WATER RESOURCES BOARD

WATER RESOURCES IN THE NORTH

Northern Technical Working Party Report

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PREFACE

(i) In May 1965 the Water Resources Board were asked by the Minister of Land and Natural Resources to examine and report upon the following matters in respect of possible barrages across Morecambe Bay and Solway Firth:-

1. the feasibility and probable costs of construction;
2. the yields and qualities of water which would be made available;
3. the demand for water, and the rate of growth of that demand, in areas which might be supplied;
4. the arrangements necessary to distribute barrage water;
5. the delivered cost of treated or partially treated water;
6. other possible sources of supply in relation to the demand at (3) above and the costs of their staged development.

(ii) Sir Alexander Gibb and Partners and Messrs. Babtie, Shaw and Morton, Consulting Engineers, were appointed by the Board to carry out the investigations under items 1 and 2 above in respect of the Morecambe Bay and Solway Firth barrages respectively. Restrictions upon capital expenditure imposed shortly after the consultants had submitted detailed proposals made it impossible to proceed with the full-scale feasibility studies of the barrages. Instead, the consultants carried out preliminary desk studies. These, together with a covering report by the Board, were published by Her Majesty's Stationery Office on 26th January, 1967. On the same day the Minister of Land and Natural Resources announced in Parliament that he had asked the Board to proceed with a full feasibility study of the Morecambe Bay scheme. It was estimated that this would cost about £500,000 and would take about 3½ years. Work on this study is now proceeding and will be completed in 1971.

(iii) Investigations under items 3-6 of the terms of reference required the study of the likely demands for water up to the end of this century for the whole of that part of England north of a line from the Mersey to the Humber and of possible sources alternative to the barrages which could meet those demands. The Board therefore convened a meeting in September 1965 with the clerks and chief engineers of each of the river authorities in the north of England, namely the Northumbrian, Yorkshire Ouse & Hull, Mersey & Weaver, Lancashire and Cumberland River Authorities. At this meeting it was decided to set up a working party (to be known as the 'Northern Technical Working Party') comprising the chief engineers of the five river authorities and representatives of the corresponding Area Committees of the British Waterworks Association, together with advisers from the Ministry of Housing & Local Government, the Central Electricity Generating Board and the British Waterways Board, to report to the Board on items 3, 4, 5 and 6 of the above terms of reference.

(iv) On the fringe of the study area account had to be taken of the possibility of planned expansion at Humberside. Development on the south bank of the river would call for the provision of additional water supplies in North Lincolnshire where local resources are already near to exhaustion and industrial demand is increasing rapidly. It was therefore decided to consider the future requirements of North Lincolnshire together with the Humberside development as a possible new export demand upon northern water resources. The Lincolnshire River Authority engineer was invited to attend the working party to advise on these requirements.

(v) In considering the demands and resources of the north west of England it became apparent that the resources of the Liverpool Corporation water undertaking and the Wirral Water Board could not be assessed properly without reference to the overall resources of the Dee & Clwyd River Authority area upon which those undertakings have become so dependent. It was therefore decided to extend the study area to include the Dee and Clwyd area and to invite the River Authority engineer and a representative of the British Waterworks Association Area Committee to join the working party. The complete membership of the working party is shown on pages v, vi and vii.

(vi) In 1966 various local authorities and government departments, including the Water Resources Board and the Dee & Clwyd River Authority, formed a Steering Committee to study the case for a crossing of the Dee Estuary, and consulting engineers were appointed. Investigations to date have shown that there is scope for combining fresh water storage in the estuary with a traffic crossing and other services. As in the case of Morecambe Bay, engineering studies are continuing and only preliminary findings are as yet available with which to assess the part which Dee Estuary storage might play, alongside other estuary works and inland schemes, in the water resources pattern of the north. Studies of the Dee Estuary seem likely to reach completion at about the same time as the Morecambe Bay studies.

(vii) Preliminary assessments of demands and available resources showed that in parts of the north demands on statutory undertakings already exceed reliable resources and that, after allowing for the additional yields authorised by the Manchester (Ullswater and Windermere) Order 1966 and the Tees Valley and Cleveland Water Act 1967, demands would overtake presently authorised resources over much of the area during the 1970's. In view of this the Board thought it desirable to make an interim report intended to serve as a basis for action until the working party had completed its investigations. This Interim Report on Water Resources in the North[1] was published by Her Majesty's Stationery Office in August 1967.

(viii) The members of the working party are grateful to their authorities for allowing them to serve on the working party and to present this report to the Water Resources Board. They would also like to thank the statutory water undertakings and other organisations who have gathered and presented information for the use of the working party.

(ix) The opinions expressed in this report do not necessarily represent the views of all the members of the working party and cannot be taken as committing any authority or organisation to the courses of action recommended in the report.

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[1] *Referred to subsequently as 'the Interim Report'*

MEMBERS OF NORTHERN TECHNICAL WORKING PARTY

Members

A. G. McLellan C.B.E., B.Sc., FICE, MIWE, J.P. (Chairman - to April 1966)	Water Resources Board
J. F. Glennie M.Sc. (Eng.), FICE, MIWE. (Chairman - April-October 1966)	Water Resources Board
B. Rydz B.Sc.Tech, FICE, MIWE, FASCE. (Chairman - from October 1966)	Water Resources Board
O. Gibb M.Eng. MICE, AMIWE.	Water Resources Board
U. T. Burston B.Sc., MICE, A.M.I.Struct.E., AMIWE.	Northumbrian River Authority
W. F. Gilbert M.A., FICE, MIWE.	Yorkshire Ouse & Hull River Authority
H. H. Crann B.Sc., Ph.D., FICE, MIWE. (from June 1966)	Dee & Clwyd River Authority
J. G. Lloyd B.Sc. (Eng.), FICE, MIWE.	Mersey & Weaver River Authority
C. Clay B.Sc. (Eng.), FICE, MIWE.	Lancashire River Authority
A. J. Collins B.Sc., MICE, AMIWE.	Cumberland River Authority
S. G. Barrett M.Sc., FICE, MIWE. Newcastle and Gateshead Water Company	British Waterworks Association North East Regional Committee Northumbrian Area
J. R. Roberts B.Sc. (Eng.), FICE, MIWE, MBIM. Leeds Corporation Waterworks	British Waterworks Association North East Regional Committee Yorkshire Ouse & Hull Area
J. H. T. Stilgoe M.Eng., FICE, MIWE. Liverpool Corporation Waterworks (from November 1966)	British Waterworks Association North Wales Regional Committee Dee & Clwyd Area
R. L. Harrison B.Sc. (Eng.), FICE, MIWE. Manchester Corporation Waterworks	British Waterworks Association North Western Regional Committee Mersey & Weaver Area

Members (Contd.)

F. Law B.Sc. Tech., FICE, MIWE. Fylde Water Board	British Waterworks Association North Western Regional Committee Lancashire Area
J. P. Williamson B.Sc., MICE, AMIWE. West Cumberland Water Board (to June 1968)	British Waterworks Association North Western Regional Committee Cumberland Area
D. S. Henderson B.Sc. Tech., MICE, AMIWE. South Cumberland Water Board (from June 1968)	British Waterworks Association North Western Regional Committee Cumberland Area
B. J. Weston (Secretary)	Water Resources Board

Advisers and Deputies

M. T. Avery	Cumberland River Authority
J. F. Bailey MICE, AMIWE. Preston and District Water Board	British Waterworks Association North Western Regional Committee Lancashire Area
G. Dalkins MICE, AMIWE, AMIMechE.	Lancashire River Authority
H. R. Davenport FICE, MIWE. Bolton Corporation Waterworks	British Waterworks Association North Western Regional Committee Mersey & Weaver Area
P. Davidson B.Eng., FICE.	Mersey & Weaver River Authority
T. G. S. Green M.Sc., MICE.	Yorkshire Ouse & Hull River Authority
H. S. Hawkins B.Eng., FICE, AMIWE.	Lincolnshire River Authority
R. W. Hustwit B.Sc., MICE, AMIWE, AMBIM. Leeds Corporation Waterworks	British Waterworks Association North East Regional Committee Yorkshire Ouse & Hull Area
T. M. Hyde MICE, AMIWE.	British Waterways Board
S. Lowndes FCIS. Wrexham and East Denbighshire Water Co.	British Waterworks Association North Wales Regional Committee Dee & Clwyd Area
M. J. Lowther B.Sc., MICE, MIWE. Newcastle & Gateshead Waterworks Co.	British Waterworks Association North East Regional Committee Northumberland Area
C. T. Marshall B.Sc., Ph.D., MICE, AMIWE.	Northumbrian River Authority

Advisers and Deputies (Contd.)

W. H. Norris B.Sc., FICE.	Ministry of Housing & Local Government
D. C. Summerton B.Sc., FICE, MIMechE, AMIWE. Liverpool Corporation Waterworks	British Waterworks Association North Wales Regional Committee Dee & Clwyd Area
P. Williamson FIEE, FIMechE.	Central Electricity Generating Board
H. Briggs DLC., MICE, MIWE.	Water Resources Board
J. Ineson B.Sc., Ph.D., PAIWE, FGS.	
H. J. Richards B.Sc., PAIWE, FGS.	
H. Speight B.Sc., FICE, MIWE, MBIM.	
D. Watson MICE, AMIWE.	

NORTHERN TECHNICAL WORKING PARTY

Report to the Water Resources Board

CHAPTER 1: INTRODUCTION

1. The area of this study is delineated by the six river authorities taking part (see Map 1). It incorporates 56 administrative counties and county boroughs and it embraces or impinges upon five economic planning regions, as well as Wales, whose councils have a close interest in the provision of water for industrial and other development. However, we have not identified the demands and resources of any local authority or planning region as a unit because many of them overlap the boundaries of river basins, within which water use and re-use must be considered as a whole, and because we have sought the most effective and economic service for the north as a whole. We have, however, allowed for the effects of certain town expansions which are under consideration in the regions.

2. Our first aim has been to establish the likely pattern of future demands on the public water supply and the future requirements of those who obtain water for their own use from sources throughout the north and to determine what additional water supplies must be made available to enable all of these to be met. This is not simply a matter of adding up individual needs because much of the water used can be water previously used in the public supply or by industrialists and discharged as effluent to watercourses.

3. In assessing the future needs of public water supply we have not allowed for any possible restriction of supply or limitation of demand (for instance, by the price mechanism) nor have we tried to compare the benefits of an unrestricted water supply with the benefits of spending public money in other directions. Expenditure per capita on water supplies is small in this country compared with expenditure on many other essential services and most people probably consider it modest in comparison with the convenience of an ample supply; moreover, the developments studied in this report do not presage any radical change in water costs.

4. There are, broadly, only two known ways in which continuous supplies could be made available to meet demands. One of these is to store fresh water when nature provides it in abundance; the other is to de-salt water from nature's great store - the sea. The latter is under continuous study by the Water Resources Board and is outside our terms of reference[1]. But it can be said that, on present knowledge, it would involve immensely greater expenditure than the storage and treatment of natural fresh water and, like the latter, would involve major problems of amenity.

5. We have tried to assess all the practicable ways of augmenting the region's water resources by storing fresh water and to compare the effectiveness of various overall strategies for meeting future need. Our terms of reference did not extend beyond the limits of the region - say, into Scotland - and in any case there are no physical or economic obstacles to meeting requirements from within the region. The problems are those of social priorities and these are unlikely to be overcome by transferring them outside the region.

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[1] *Details of latest cost estimates of various desalination processes have been reviewed in W.R.A. Technical Paper No. 60, 1967.*

6. The aim of water resource studies in the past has been to identify and select schemes which would match the needs of a particular water undertaking or a group of undertakings. In this regional study, however, we have not sought sources adapted to the individual needs of existing undertakings but have tried to determine programmes of development which will most economically serve the region as a whole. In order to operate such an optimal physical system certain changes in the organisation and administrative control of the water supply system may be necessary. In this connection reference is made at the end of Chapter 5 to certain problems arising from present statutory obligations.

7. The region is not entirely isolated in respect of water supplies, and transfers particularly from the north to regions further south may well increase in future decades. It is our view, nevertheless, that the region delineated for the purpose of this study can be effectively planned as an organic whole for the period to 2001, possible transfers across its southern boundary being dealt with as special links between this and an adjoining region. Some of the implications of increased transfers have been examined and reference is made to these in Chapter 7 of the report.

8. There are many possible new storage sites in the north, including estuary sites, and the combinations and sequences in which they could be used are very numerous. Our analysis is designed to take account of the comparative merits of all these possibilities but only a few development 'programmes' can be explicitly set out in this report. With these, however, we have sought to illuminate the more significant choices in water strategy for the north as a whole and the comparative costs of following one course rather than another. The social advantages or disadvantages of any course must be weighed against these costs.

9. Apart from the analysis of costs, there is no objective way of making comparisons. It may be thought that more thorough-going cost/benefit analysis would have enabled us to widen the field of objective comparison. Although the estuary studies may prove to be an exception, we consider that for the generality of schemes the tools we have to hand for measuring supplementary benefits of any kind are altogether too clumsy to identify the advantages of, say, one reservoir site over another. In any case such differences are not likely to be significant in monetary terms, bearing in mind that - given our basis of estimate - differences of 1% or 2% in programme cost are probably without meaning.

10. It must be remembered that detailed studies of hydrology and water quality together with surveys and site investigation will be needed to assess and design schemes in detail and that individual yield and cost estimates used in this report - particularly those of the estuary schemes - will be subject to review in the light of these. Furthermore, the study of local water availability and quality in rivers which are subject to repeated industrial abstractions and effluent returns is one which will exercise individual river authorities for a long time to come. The same is true of the determination of acceptable flow requirements at particular points for the health and amenity of each river and hence of permissible abstractions from rivers. It is not to be expected, therefore, that individual schemes will turn out in detailed accordance with our assessments.

11. In addition to these uncertainties our estimates of the growth of demand may prove to be materially in error in location and/or in time; our economic assumptions (discount rates, price relationships, etc.) may prove inapposite; and attitudes to amenity and recreation may change appreciably over the years.

Nevertheless, we have tried to frame our assumptions and analyses so that, as far as possible, valid comparative conclusions can be drawn.

12. Both long-term forecasts of water needs and any plans which are evolved to meet them will be subject to repeated review and adaptation as time goes on. Nevertheless, plans must be made with an eye on some long-term estimates of needs. We believe that our estimates together with the other information we have assembled and the further site investigations called for will provide a valid basis for the comparison of regional strategies or 'framework plans' within which river authorities and water undertakings can formulate detailed proposals. The survey of the resources of their areas and the evolution of suitable plans of development is of course an essential function of river authorities under Section 14 of the Water Resources Act 1963.

CHAPTER 2: DEMANDS AND RESOURCES OF STATUTORY WATER UNDERTAKINGS

Historical

13. The existing conservation and distribution arrangements in the north developed mainly from expedients appropriate to the technology and economic attitudes of the nineteenth century. Until the early years of that century the water user, whether as householder, farmer or manufacturer, looked to nearby springs or wells or to the relatively unpolluted rivers. In relation to the readily available resources, domestic and industrial needs were small. Storage, where it was needed for mills or other works, was a simple matter which bardly affected the river flow.

14. As manufacturing processes became more complex and the numbers of people in the industrial centres grew, local wells and springs became inadequate and the rivers and streams more heavily polluted. The needs of the towns made them look for supplies from storage, and the obvious sites were those in the uplands near to them, from which water could gravitate through pipelines. By the second half of the nineteenth century, large reservoirs and supply systems had been developed in many parts of the north. As demands continued to increase almost every water catchment in and near to the developing centres of the region came into use to supply the towns by means of reservoirs and piped water mains or to satisfy the needs of riparian owners.

15. It therefore became necessary, particularly for the large cities, to look further afield; Liverpool, for instance, turned to the mountains of North Wales and Manchester to the Lake District. There water was available in large quantities, and excellent opportunities existed for storage at high level. Manchester Corporation, whose experience is in many ways representative of that of other large northern centres, became responsible for bulk supplies to other undertakings when it sought authority to develop the Thirlmere catchment in Cumberland, raise the level of the lake and construct an aqueduct to link the new source to the city. Parliament required that Manchester should supply water on demand to any other water undertaking within the vicinity of the route of the aqueduct. Again, when Manchester was authorised in 1919 to acquire Haweswater and adjacent areas in Westmorland, further and wider obligations were imposed; and any water undertakings within the vicinity of the Thirlmere and Haweswater aqueducts or whose limits of supply adjoined those of Manchester were given rights to reserve bulk supplies.

16. In much the same way other undertakings with the staff and technical resources to exploit large storage projects in remote areas became responsible for bulk supplies to others and major water conservation projects were promoted to meet the growing needs of combinations of water undertakings. On the eastern side of the Pennines Sheffield, Derby, Nottingham and Leicester combined as long ago as 1899 to form the Derwent Valley Water Board to develop supplies from the Derbyshire Derwent. More recently in 1961 Sheffield combined with Leeds, Barnsley and Rotherham in a scheme to abstract water from the Yorkshire Derwent at Elvington near York.

17. In the examination of some of these proposals the possibility of even larger groupings of towns combining in major projects has sometimes been canvassed. Sources in the Lake District were suggested to help meet the needs of Liverpool, Newcastle, Manchester and even London as far back as 1866. When in 1962,

following the rejection of proposals to use Ullswater for water supply, a conference on water resources in the North West was set up under the chairmanship of Lord Jellicoe, many suggestions were examined including the wider use of water brought from Wales for Liverpool.

18. A corollary to this trend has been the reduction in the numbers of water undertakings in the region in recent decades. The process of regrouping has reduced their number from some 300 in 1950 to 82 and is continuing.

Present Statutory Water Undertakings

19. At 31st March 1968 there were 82 statutory water undertakings supplying the area. Their limits of supply are shown on map 2, accompanying this report. They vary in size from the largest supplying over 120 million gallons per day (m.g.d.) in 1967 to the small rural district council supplying only 20,000 gallons per day. The twelve largest undertakings provide about 60% and the two largest undertakings about 25% of the total supply of 916 m.g.d. The consumption per capita in 1967 was 61.5 gallons a day, which is higher than the national average of 55.7 gallons a day owing to a higher demand by trade and industry. The domestic consumption at 35 gallons a head (which includes distribution losses) is just below the national average of 36 gallons a head.

Growth of Demand

20. As in other parts of the country domestic demand must be expected to increase both from an increase in the population and from a continuing increase in per capita use of water consequent upon rising standards of housing and the spread of water-using appliances. This increase will be accompanied by an increase in demands on the statutory water undertakings by industrial users. The undertakings have supplied figures of present and estimates of future demand for both domestic and industrial supplies and the Ministry of Housing & Local Government have provided estimates of future population migration, planned growth and natural increase. The population of the north is expected to increase by just over one million by 1981, and by nearly four and a half millions by 2001.

21. Future demands have been estimated by extrapolating previous trends and by making allowance for planned growth, e.g. Central Lancashire New Town, Humberside, etc. The Working Party made no attempt to impose uniformity of approach and individual undertakings adopted the method they most favoured. The choice fell almost equally between extrapolation of total demand trends or application of per capita demand trends to expected population growth.

Demands and Resources

22. Table A shows for each river authority area estimated population and water demand in respect of public water supply for 1967, 1981 and 2001. The total estimated demands at 2001 represent an average (simple interest) annual growth rate of 3.2% of the 1967 figures (between 1955 and 1967 the national rate of growth averaged 3.3% of the 1955 figure). For comparison the estimates adopted in the Water Resources Board "Report on Water Supplies in South East England" implied a growth rate of 3.1% between 1965 and 2001. The corresponding implied per capita consumptions at 2001 for the North and the South East are 100 and 80 gallons per day. The difference lies in a much higher estimated trade and industrial demand of 49 gallons per head in the North compared with about 30 gallons per head in the South East. From past history and present trends

TABLE A

PUBLIC WATER SUPPLY

POPULATION AND PER CAPITA DEMAND

RIVER AUTHORITY	1967					1981					2001				
	Ministry Estimate of Population	Total Demand	per capita demands (g.p.d.)			Ministry Estimate of Population	Total Demand	per capita demands (g.p.d.)			Ministry Estimate of Population	Total Demand	per capita demands (g.p.d.)		
	(thousands)	(m.g.d.)	Metered	Domestic	Combined	(thousands)	(m.g.d.)	Metered	Domestic	Combined	(thousands)	(m.g.d.)	Metered	Domestic	Combined
Northumbrian	2,723	185	38	30	68	2,910	293	59	41	100	3,400	417	74	49	123
Yorkshire Ouse & Hull	4,553	239	19	34	53	4,930	329	25	42	67	5,900	470	28	52	80
Dee & Clwyd	434	23	17	36	53	490	41	32	52	84	600	58	37	60	97
Mersey & Weaver	5,159	340	30	36	66	5,530	490	43	46	89	6,500	660	51	51	102
Lancashire	1,624	102	24	39	63	1,900	158	35	48	83	2,400	224	39	54	93
Cumberland	306	27	41	47	88	320	65	150[1]	53	203	400	93	175[1]	58	233
TOTALS/ AVERAGES	14,799	916	27	35	62	16,080	1,376	41	44	85	19,200	1,922	49	51	100

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1. *These very high figures arise from the allowances which have been made for prospective supplies to new industries which are likely to be attracted to the West Cumberland Development Area by the availability of plentiful and cheap water. It is assumed that in the Cumberland RA area all new industrial demands will be met from the public water supply (see Chapter 3 para. 42).*

there seems no reason to doubt the validity of the higher northern estimate. Diagram 14 of Appendix III shows the estimated future growth of demand for the whole area compared with the actual growth of a few of the major undertakings over the past half century.

23. More detailed information for each statutory water undertaking is given in Appendix I which consists of a set of tables for each river authority area. Table I of each set shows for each undertaking (or the part of an undertaking in the area of that river authority) the 1967 demand and the estimated future demands in 1981 and 2001. The total demand on an undertaking extending into more than one river authority area is, of course, the sum of the parts. The figures in all cases have been calculated as average annual demands.

24. Most demands for water show some variation during the year and the demands on some undertakings (especially those serving holiday resorts) show pronounced summer peaks. They must have capacity in hand to meet those peaks although the average amount they safely supply throughout the year is much lower. In this report the resources available to an undertaking are taken to be equal to the average supply which that undertaking could provide throughout the year bearing in mind the characteristics of its own demand curve. Authorised resources are those for which the undertakings have all the necessary powers to abstract water, acquire land and construct works, their yield being defined as above. For simplicity in calculating future deficiencies it has been assumed that all authorised resources could be in use by 1971[1].

25. Transfers of water between river authority areas are shown in Tables II and III of Appendix I. For the future it has been assumed that such transfers will continue to the extent that water is available for transfer, and as between two undertakings to the limit of any authorised arrangements.

Effective deficiencies

26. The authorised net resources for each undertaking are listed under the river authority area in which they occur. The apparent balance of each undertaking is obtained by subtracting estimated future demands from authorised net resources and the resultant surpluses or deficiencies are tabulated. Since it cannot be assumed that the surpluses within a river authority area are automatically transferable to offset deficiencies elsewhere in the area, these are totalled separately. The effective deficiency in each river authority area is obtained from the sum of the individual deficiencies less the imports to the area and is shown in Table IV of Appendix I.

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[1] *In practice this assumption is not entirely warranted: see Chapter 5.*

27. The effective deficiencies, disregarding any un-used surpluses, have been abstracted to Table B below. This shows the amounts which have to be made available by new schemes or by the transfer of surpluses from one undertaking to another.

TABLE B PUBLIC WATER SUPPLY

DEMANDS AND DEFICIENCIES

River Authority	Average daily demands m.g.d.			Effective deficiencies on authorised resources nearest 5 m.g.d.	
	1967	1981	2001	1981	2001
Northumbrian	185	293	417	45	165
Yorkshire Ouse & Hull	239	359[1]	570[1]	85[1]	290[1]
Dee & Clwyd	23	41	58	10	25
Mersey & Weaver	340	490	660	65	225
Lancashire	102	158	224	40	105
Cumberland	27	65	93	20	50
Totals	916	1,406	2,022	265	860

This table includes provision for the possible demands of North Lincolnshire and planned development at Humberside on the supposition that these demands could not be met from sources within the Lincolnshire River Authority area and may have to be met from sources in the north.

28. The effective deficiencies at particular dates (1981 and 2001) are, of course, representative of a steadily growing demand. It must be borne in mind, however, that resources are not normally augmented each year but by the periodic development of sources. It is therefore usually necessary to have some supplies in hand to cover the period while a new source is being developed.

29. The effective deficiency in 1981 is considerably less than the increase in demand (1967-1981) shown in Table B. This is because the yield of authorised resources exceeded demand in 1967 by about 200 m.g.d. The extent to which these surpluses will continue to meet the demands of the parent undertaking or can be used to meet deficiencies elsewhere is discussed in Chapter 5.

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[1] *Including North Lincolnshire/new Humberside conurbation.*

CHAPTER 3: DIRECT INDUSTRIAL AND AGRICULTURAL DEMANDS

Overall Use

30. The early and rapid industrialisation of the north of England owed much to the plentiful supplies of good quality water available there. From the beginnings of textile manufacture in the late eighteenth century to the rapidly expanding chemical plants of the present day a major proportion of the country's most important water-using industries has been established in the north.

31. On the other hand agriculture, and particularly cultivation of crops which have a high value in relation to irrigation cost, is of much less general importance than in south-east England. Because of this and because of the relative abundance of rainfall over most of the area we have made allowances for irrigation demand only in a few places - such as the East Riding of Yorkshire - and they have been incorporated in general figures of industrial need.

32. About 400 million gallons a day of water are supplied from the public water supply to metered consumers in trade and industry in the six northern river authority areas, some 25% of it in the industrial concentrations (largely of chemical manufacture) on Teesside and Merseyside. 400 million gallons is equivalent to about 27 gallons per head of the population whereas the comparable average figure for the rest of England and Wales is only about 20 gallons per head.

33. Moreover, certain of the industries of the north have long been accustomed to procuring their own water supplies by abstraction from nearby rivers or from underground sources. These are referred to in this report as direct industrial abstractions and they now require licences from the river authority under the Water Resources Act. Licensed abstractions for industrial use (excluding the Central Electricity Generating Board) exceed 2000 m.g.d. and amount to considerably more than those in the rest of England and Wales. Over 80% of this is licensed by the Northumbrian, the Yorkshire Ouse & Hull and the Mersey & Weaver River Authorities.

34. Metered public supplies and private industrial direct abstractions in the six northern areas together account for about a half of the total industrial and trade use (excluding C.E.G.B.) in the twenty-nine river authority areas of England and Wales.

Characteristics of Industrial Use

35. Water is used in industry mainly to carry dissolved or suspended matter or to transfer energy either as part of the productive process or to dispose of waste. Any continuing input of water serves to offset discharges of effluent together with water evaporated in cooling or consumed in other ways. The effluent normally carries contaminants or rejected heat or both. It is often possible to reject the heat to atmosphere by introducing evaporative cooling, at the cost of increased net use of water at the factory site; it may also be possible to re-use the effluent for other purposes on the site but unlesa the contaminants can be separated out this will usually lead to a more concentrated effluent.

36. Unlike the public water supply undertakings, industrial abstractors rarely develop major storage works. They are therefore dependent on the 'run of the river' (or on continuous abstraction of ground-water) although they may benefit indirectly from the reliable flows of sewage effluent resulting from the use of water conserved for the public supply.

37. It is only exceptionally that industrial abstractors divert water from natural watercourses for any great distance; effluents are usually returned to watercourses fairly close to the point of abstraction and are frequently available for re-use by other abstractors on an inland watercourse. In such circumstances increased re-use within a factory, although reducing the required abstraction for that factory, may be of general benefit only if it leads to absorption, separation or breaking down within the process of contaminants which would otherwise interfere with re-use by other abstractors.

38. For these reasons it is not generally convenient to consider industrial abstraction in the terms appropriate to the public water supply - as simple totals of demand which can be compared with the reliable output of specific sources. On the contrary, it will be necessary to analyse the needs of riparian industry in relation to the services which a watercourse can satisfactorily perform from point to point along its length, taking account of water quality and temperature and of both abstractions and effluent returns. These complex investigations will call for the acquisition of much new data and will be a continuing task for river authorities in the future.

Net Industrial Demand

39. Meanwhile as an expedient industrial areas have been divided broadly into

(a) coastal and estuarial strips where there will be little opportunity for successive re-use; and

(b) industrialised river valleys where industrial abstractors may benefit from new discharges of sewage effluent and where increases in the net use by a succession of abstractors may be small or even negligible in comparison with such discharges.

Balance sheets in the form of 'residual flow diagrams' have been prepared for certain of the latter and are given in Appendix II.

40. In the Interim Report it was suggested that direct water abstraction by industry in the north in 1965 (including C.E.G.B.) was nearly 4000 m.g.d. gross (approaching 300 m.g.d. net)[1] and that new net demand by industry, making no allowance for the re-use of sewage effluents, would rise from 64 m.g.d. in 1971 to 444 m.g.d. in 2001. This included an allowance rising from about 30 m.g.d. in the early 1970's to nearly 100 m.g.d. at the turn of the century for evaporative losses from C.E.G.B. power stations sited on non-tidal rivers. It seems likely that these inland stations can be located close to electrical load centres in the industrial valleys referred to in para. 39.

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[1] *Total licensed abstractions at 30th September 1967 together with estimates of net use are given in Table C.*

TABLE C

INDUSTRIAL WATER USE

(INCLUDING AGRICULTURE AND CENTRAL ELECTRICITY GENERATING BOARD)

River Authority	River or Area	Type[1] of industrial zone	Licensed[2] total quantities at 30.9.67. nearest 5 m.g.d. equivalent	Net Use factor percentage of gross use
NORTHUMBRIAN	Tyne/Coquet	a & b	50	15
	Wear	a	5	45
	Tees	a	30	95
	Abstractions from tidal waters	–	2135	–
YORKSHIRE OUSE & HULL	Aire	b	190	5
	Calder	b	1040	less than 5
	Don	b	490	5–10
	Other areas including tidal waters	a & b	900	–
DEE & CLWYD	Dee including tidal waters	b	90	70
	Flint coast	a	15	100
	Other areas including tidal waters	b	5	–
MERSEY & WEAVER	Mersey & Irwell above Irlam	b	880	less than 5
	South East Lancashire	b	400	less than 5
	Weaver/Dane/Gowy	b	90	less than 5
	Wirral & Liverpool	a	80	100
LANCASHIRE	Lune/Wyre	a & b	160	5
	Ribble/Calder	b	65	5
	Douglas	b	25	5–10
	Fylde coast	a	15	100
	Other areas	a & b	80	–
	Abstractions from tidal waters	–	175	–
CUMBERLAND	West Cumberland	a	55	70
	Eden	b	80	5
	Other areas	a & b	5	–
	TOTAL		7060	

1. *a = coastal or estuarial strips*
   b = industrial river
2. *Includes abstractions from tidal waters not included in the Interim Report.*
   Equivalent daily quantities are taken as total annual quantity divided by 365.
   Actual daily use in 1967 is estimated at approximately $\frac{2}{3}$ *of the licensed quantities.*

41. We have now concluded that in these industrial valleys - principally the valleys of the Aire, the Calder, the Don, the Mersey and the Ribble - new net industrial demand, including that for power stations, is likely to be entirely met by net additions of public sewage effluent although in a few cases such as the Dane/Weaver system special measures will be necessary including new local storage schemes given in the schedules of resources in Appendix IX.

42. The remaining industrial areas - principally the coasts of Durham, Flintshire, Merseyside and the Fylde - account for the residual deficiencies adopted for the purposes of this report and indicated in Table D. They amount to about 50 m.g.d. in 1981, growing to about 100 m.g.d. in 2001. Two other coastal areas - Humberside and West Cumberland - may similarly be areas of considerable net industrial use but in these two cases generous allowance has been made in the estimates for public water supply.

43. The outcome is that the net demand figures listed in Table D have been allocated to six of the thirteen demand districts identified in Chapter 5, being added to the estimated future public water supply deficiencies of those districts. These district deficiencies are used later in this report for the regional comparisons of resources.

TABLE D

DIRECT INDUSTRIAL ABSTRACTION DEFICIENCIES

Demand District	Net Deficiency - m.g.d.		River Authority Area
	1981	2001	
Newcastle	3	6	Northumbrian
Sunderland	2	4	
Teesside	13	30	
Flint/Denbigh (Flint Coast)	13	28	Dee and Clwyd
Chester (Wirral Peninsula)	1	2	
	5	15	Mersey and Weaver
Fylde	7	18	Lancashire
Totals - To nearest 5 m.g.d.	45	105	

CHAPTER 4: SURVEY OF POTENTIAL RESOURCES

Overall Resources

44. Over the whole of the six river authority areas of the north residual rainfall - rainfall minus evaporation and transpiration losses - averages about 15,000 million gallons per day. However, the minimum natural flow in rivers and underground strata, together with contributions available from man-made storage, is assessed for practical purposes at some 2,500 m.g.d., about a half of it contributed by releases from storage.

45. These flows are at present affording the continuous supplies to the statutory water undertakers, industry and agriculture referred to in Chapters 2 and 3 as well as providing the residual flows in the rivers. Total present abstractions alone exceed the combined minimum flows and this is possible only because of the re-use by industry either of industrial effluents or of effluents resulting from the public water supply.

46. Residual flows are required to maintain outfall channels, for navigation, to dilute effluents, in the interests of fisheries or for amenity reasons. Assessment of the minimum residual flows required for all these purposes is a complex problem and no formal determinations of the minimum acceptable flow (in accordance with Section 19 of the Water Resources Act) have yet been made by the river authorities. By and large, however, it is considered that dry weather flows cannot be reduced appreciably below their present levels without injury to other interests and any substantial increase in continuous supplies is contingent upon the provision of further storage.

47. The usual way of providing such storage has been by flooding valleys to form reservoirs - existing impounding storage in the north aggregates about 150,000 million gallons or about 3% of average annual residual rainfall - but there are also possibilities of storing water in estuaries near mean sea level (for example, by estuarial barrages) and of developing storage in underground aquifers by intermittent or variable pumping.

48. Regardless of the form which the storage takes it enables water to be held over from times of plenty to drier periods and, in conjunction with a catchment area - a river system or an area of ground receiving percolating rainfall - it enables a continuous supply to be provided. After use such a supply may be discharged to a river from which another user abstracts water downstream. In this way a single source work may guarantee two or more supplies and the primary yield of new storage works may thus be somewhat less than the sum of the new needs that must be met.

Transfer of Surpluses and New Sources

49. Before assessing the need for new developments, existing resources which are not yet fully used are first considered. In the public water supply sector reliable supplies exceed the 1967 demand by about 250 m.g.d. In the industrial sector surpluses, or deficiencies, cannot be so simply identified because of the complexities introduced by the re-use of effluents, as described in Chapter 3. The extent to which the public water supply surpluses may be deployed to meet short term deficiencies elsewhere is discussed in Chapter 5.

50. Most of the information on new sources of supply and schemes for increasing reliable resources has been supplied jointly by the river authority engineers and the British Waterworks Association representatives for each area. The proposals include a small number of schemes which water undertakings have thoroughly investigated but the bulk of the proposals have been subjected to preliminary desk analysis only and for these detailed site investigations will be required to confirm feasibility and costs. The potential developments in each river authority area are set out in Appendix IX in two groups: isolated sources on the one hand and, on the other, storages which are of regional significance either because of their size or because they can be used for the regulation of major rivers.

Isolated Sources

51. In Part I are listed 'Isolated Sources'. These are sources, usually of local or comparatively minor importance, some of which have been under consideration by a particular water undertaking and are especially convenient for that undertaking. They include continuous river and ground-water abstractions without storage (in areas where these are permissible), new reservoirs and modified use of compensation water from existing reservoirs; they are either in river basins which are not suitable for overall regulation or in localities elsewhere where they will not sensibly affect the overall pattern of river regulation.

52. The developments so listed have been placed in broad ranges of cost of water as delivered into an appropriate distribution system. Because they are located nearer to the centres of demand they should, other things being equal, provide supplies more economically than schemes involving long aqueducts from remote sources. On these and more general grounds a percentage of their combined yield has been assessed as the likely total development in this category which may be assumed to offset a corresponding amount of the future needs estimated in Chapter 5. The total supply expected from these schemes amounts to about 125 m.g.d. and the potential and likely amounts in each river authority area are given in Table E below.

TABLE E

ISOLATED SOURCES

River Authority Area	Estimated yields to nearest m.g.d.	
	Total potential	Assumed extent of development
Northumbrian	28	12[1]
Yorkshire Ouse and Hull	42	25
Dee and Clwyd	2	2
Mersey and Weaver	82	60
Lancashire	18	10
Cumberland	51	14
TOTALS (nearest 5 m.g.d.)	225	125

[1] Temporarily 19 m.g.d. - see Appendix IX, Schedule I.

53. It will be noted (from Appendix IX) that the schedule of isolated sources for the Mersey and Weaver area is much more comprehensive than that for any other area. This is because the rivers in this highly industrialised area offer little opportunity for major regulation and all sources of supply considered have been included in the category of isolated sources. Approximately one quarter of the yields so listed comprise additional ground water abstractions, mainly within schemes for use in conjunction with surface water. Further information about these and about existing groundwater abstractions is given in Appendix V.

Regional Storage for River Regulation and Direct Supply

54. All other developments (listed in Part II of Appendix IX) have been considered in terms of the part they could play in an integrated regional pattern of water resources. They could be used to give direct supplies by pipeline to certain areas, in the traditional way, or alternatively to regulate the principal rivers of the region, enabling them to support new abstractions downstream.

River Regulation

55. In river regulation, the run-off of the river system to some abstraction point in the lower reaches is made up in times of low flow by using stored water. This is usually done by releasing water down the river from a reservoir during periods when the natural flow at the abstraction point falls below some predetermined rate at which the required abstraction is permissible. For any given rate of abstraction such periods are less frequent and less protracted in the lower reaches of a river than at an upland reservoir site, so that less water is required from the reservoir; conversely a given reservoir is able to sustain a greater reliable supply than it could yield by 'direct supply' from the upper reaches. In most cases, moreover, the river course takes the place of a portion of the delivery pipeline; thus only a comparatively short section of the river (below the abstraction point) suffers an overall loss of flow and the length of the pipeline can be reduced. For those reasons, and in spite of greater treatment and pumping costs, this technique is preferred in current water resources planning and occupies a central place in this report.

56. The northern rivers which have been considered for regulation have a combined average daily flow (A.D.F.) of 7,500 m.g.d. If they were all developed equally to provide regulated yields of 33% of A.D.F., supplies amounting to some 2,500 m.g.d. would be made available. This would be more than twice the deficiency at 2001, estimated in Chapters 2 and 3, even without taking account of isolated sources or potential barrage supplies. It is unlikely that all rivers will be equally developed but it is considered that for economic and other reasons the development of any one river system beyond this point will probably not be justified. For this reason our yield assessments have been calculated to be valid up to this point and in listing storage sites the aim has been to include sufficient storage to represent this degree of development on all the river systems if possible. Alternatives have been sought and included for single large reservoirs whose development might not prove feasible but the schedules have otherwise been curtailed once this target has been achieved.

57. The major potential resources of each of the six river authorities are listed in the appropriate Schedule II in Appendix IX. In these schedules each river system which offers substantial opportunities for regulation is considered in turn. In practice, the lists of potential storage sites are reasonably

comprehensive excepting in certain areas, such as the Lake District, where a comprehensive list would be of inordinate length and where the total storage represented would go far beyond the above limit of development. It is emphasised that this extensive information has been assembled so as to provide opportunities for comparison and selection; the process of selection from the schedules, whether on economic or other grounds, is described in Chapter 7.

58. The storages listed include existing direct supply reservoirs which could be used for regulation as well as new impounding and pumped storage reservoirs. During the survey of possible storage sites attention was paid to the possibility of using low value land in the coastal margins as sites for pumped storage reservoirs. On such sites reservoirs would normally be formed by a continuous encircling embankment and would be more expensive to construct than storages of similar capacity on a natural reservoir site. The additional cost might, however, be acceptable if land of little value to other interests was used. Apart from estuary storage, whose possibilities will be covered by the major barrage studies, little opportunity was found for such developments in the north. Isolated cases which were identified are included in the schedules.

59. The regulated yields listed include some contributions from underground storage - i.e. storage generated by pumping from below ground to sustain flows in dry weather, and replenished during wetter periods. There are, however, some fairly extensive aquifers in the north - in the Vales of Eden, York and Pickering, for instance - which might be used in this way to give supplies on a somewhat greater scale. Not enough is yet known about the properties of these aquifers or the engineering and economics of these possibilities to give them further weight in our present calculations, and it is very unlikely that they would make major inroads on our overall deficiencies. More information is given about the technical problems, however, in Appendix V.

60. As listed for individual regulated systems, and within the 'limits of yield' for each river the inland storages in the schedules would afford a total supply of about 2,250 m.g.d. without allowing anything for re-use. The disposition of these supplies within the river authority areas is shown in Table F, and the location of storage sites on maps 5A, B and C.

TABLE F

YIELDS FROM REGULATED RIVERS

SUMMARY OF SCHEDULES II APPENDIX IX

River Authority Area	Possible new yield from individual river systems (nearest 50 m.g.d.)
Northumbrian	500
Yorkshire Ouse and Hull	400
Dee and Clwyd	150
Mersey and Weaver	-
Lancashire	750
Cumberland	450
TOTAL	2,250

This total would be in addition to the 125 m.g.d. from isolated sources referred to in paragraph 52.

61. The way in which we have assessed the yields available from regulated rivers is explained in Appendix IX. On the basis discussed there, and after making conjectural allowance for the residual flow requirements of the rivers, a standard linear relationship between effective storage and yield has been adopted for regulating schemes on all rivers in the north where the abstraction point is inland and above the tidal limit; it has in fact been assumed that the required volume of effective regulating storage is 172 times the daily yield to supply (Appendix IX, Diagram 3).

62. It must be emphasised that these assessments of yield are only approximate, because of the many uncertainties and assumptions governing their prediction, and represent the average yield of a sequence of schemes making up the overall development of a regulated river system. It may be found that this approach under-estimates the yield at early stages of regulation. If this should prove to be the case then succeeding schemes may be postponed to a later date than we have envisaged (see Chapter 7) but their yield is likely to be correspondingly reduced to produce the same average for the total development.

63. The probable yields assessed in this way are tabulated in the schedules together with a corresponding unit cost of water in pence per thousand gallons. These costs are given as the conservation cost appropriate to the scheme and are the estimated costs of water available in the river at the abstraction point assuming that the yield of the scheme has been fully taken up. These figures thus offer an initial comparison of the relative economy of alternative schemes within a river system.

64. In certain cases an alternative abstraction point may be developed at or beyond the tidal limit, by constructing a tidal barrier with suitable gates or weirs. At these tidal barriers lower residual flows may be acceptable and greater yields may therefore be made available to supply. In some cases tidal barriers may add to storage by themselves impounding a limited amount of fresh water, adding further to available yield. The additional increments of yield which might accrue in these ways are tabulated against the first schemes in the schedules, with a conservation cost based upon the estimated cost of the tidal barrier. Combined yields, and costs, for inland storages used in conjunction with a tidal barrier are also given where appropriate. It should be noted that if the order of development is changed from that implied by the schedules, then the tidal barrier increments will have to be reassessed for the schemes which will be the first implemented as described in Appendix IX.

65. Summary Table I in Appendix IX collates all the potential storages considered, and covers some of the possibilities of regulation of river systems with storage listed under other systems, and possibly in other river authority areas. These alternative uses afford opportunities not listed in the tables of individual river systems, but it must be remembered that the available yields would be alternative to some of the yields so listed and totalled in this summary table.

66. Summary Table I is then extended to indicate the possible range of distribution of water from each source (the 'command' area), bearing in mind the scale of yield and the location of the sources relative to the pattern of demand including, where export potential exists, areas outside the parent river authority. The estimated unit costs of water from each source delivered within its possible command area are given. For this purpose thirteen notional delivery points of representative location and level have been chosen, (see Map 2).

In each case the cost which has been quoted is the estimated cost of water conserved, abstracted, treated and delivered into notional storage at the appropriate delivery point. The basis of the unit costing used in these tabulations is given in Appendix VIII.

67. Water abstracted from the lower reaches of rivers will usually be of poorer quality than that given by upland direct supply reservoirs and will be more expensive to treat. In addition, in certain cases the introduction of such supplies into areas accustomed to soft upland water may present new treatment problems over and above those of treating the supply to potable standards. For instance, some industrialists might have to undertake treatment to remove constituents which are not detrimental in the public supply. These problems are discussed in Appendix IV and allowances have been included where necessary in the delivered unit costs listed in the summary table to cover these contingencies.

Direct Supply

68. As an alternative to their use in regulating river flow nearly all the storages listed in Schedule II could be used as direct supply reservoirs from which water would be piped directly to its destination. The yields obtainable in this way will generally be less than the corresponding regulated yields from the same storage. Nevertheless, because of reduced treatment costs and reduced pumping costs owing to use of the natural reservoir head, direct supply reservoirs might in some circumstances provide water more economically than the regulating schemes listed. They must therefore be evaluated for comparison.

69. On the basis of the assumptions stated in Appendix IX the potential storage sites listed in Schedule II have been evaluated as direct supply reservoirs. The total supply obtainable in this way is estimated at about 1,400 m.g.d. as compared with about 2,250 m.g.d. available by using these same storage sites for river regulation. The direct supply storages and yields are listed in Summary Table II. Conservation costs have been calculated in the same way as described above for regulating schemes and final delivered water costs tabulated for destinationa within the command area of each source.

Storage in Estuaries

70. The following approximate potential maximum yields have been suggested by the consulting engineers who have made preliminary studies of estuarial barrages: -

Dee	300 m.g.d.
Morecambe	500 "
Solway	600 "
Total	1,400 "

For comparison with the inland yield assessments adopted in this survey, however, we have estimated the probable yield of the gross storage of 55,000 m.g. in Morecambe Bay at 450 m.g.d. (See Appendix IX, Para. 32). For Dee Estuary we have assumed a yield of up to 250 m.g.d., which allows for the prior development of further regulated yield on the River Dee upstream of the estuary. By combining yields from estuary storage with regulated yields from the inland storage listed in the schedules it is estimated that overall yields exceeding 3,000 m.g.d. could be obtained. The estuary schemes are also included in

Summary Table I, cost data for this purpose having been taken from the consulting engineers' preliminary reports.

Delivered Unit Costs

71. Costs are given in the summary tables of Appendix IX per thousand gallons of water delivered to each demand centre from all relevant schemes - regulating reservoirs, direct supply reservoirs, estuaries, etc. These furnish a general guide to the comparative economics of various schemes and combinations of schemes, assuming that the incidence of local distribution cost (i.e. distribution beyond the thirteen delivery points) will not vary greatly with the choice of source or with the pattern of the strategic delivery network. The number of permutations of possible sources and delivery patterns is evidently very great and the next step must be to select certain sequences of development, on the basis of the tabulated unit costs, for more complete comparison of effective costs over a period.

CHAPTER 5: BALANCE OF DEMANDS AND RESOURCES

Balance by River Authority Areas

72. In Tables B of Chapter 2 and D of Chapter 3 we have given the effective deficiencies of public water supply and industry (including agriculture) in each river authority area. In Chapter 4 we have indicated the potential inland sources which are available to meet those demands. Consideration of the balance of demands and resources for each river authority area indicates those areas which are likely to be self-sufficient, those which may have to look for imports to meet future demands and those where export potential exists. This balance for each river authority area considered in isolation is given in Table G overleaf assuming that the existing and authorised transfers shown in Tables II and III of Appendix I continue.

73. In preparing optimum regional development plans, however, it is necessary to compare the costs of developing alternative sources, treating the water and delivering it to representative destinations throughout the north. For this purpose the river authority area is too large a unit, and the statutory water undertakings' service reservoir locations are too numerous to permit simple analysis and presentation.

Balance by Demand Districts

74. We have therefore divided the area into thirteen demand districts. These are groupings of statutory water undertaking areas - based largely on existing conurbations - within which the requirements of the district can be represented by the sum of the components at a notional delivery point at the centre of gravity of demand. It must be pointed out that these groupings are not identical with the demand zones adopted as an expedient for the consideration of the short-term deficiencies in the Interim Report. The thirteen demand districts and delivery points are shown on Map 2 which also indicates those, mainly rural, areas where future supplies have been assumed to come from local sources independently of any regional scheme.

75. For each district the public water supply demands, resources, surpluses and deficiencies have been abstracted from Appendix I and summarised as was done previously for the river authority areas. In this case, however, the net resources have been taken as the total authorised resources, regardless of whether they originate inside or outside the district, after allowing for existing statutory bulk supplies or supplies transferred under agreement. Net industrial deficiencies are then added as appropriate to give total effective deficiencies at the census dates.

76. The extent to which surpluses can be redeployed to meet deficiencies elsewhere was indicated in the Interim Report, assuming that in certain cases new links would be established. Delay in the development of Manchester's Lake District sources has necessitated some variation in the assumptions made in that report. These variations have been taken into account in determining the deficiency dates at which new supplies would be required in the thirteen demand districts as shown on the diagrams 1-13 (Appendix III) and as described in paragraphs 80 to 101 following. The expected yields of new isolated sources (para. 52) have been deducted from the effective deficiencies (after transfer of certain surpluses) to give final net deficiencies for each district. These will have to be met by a regional conservation programme.

BALANCE OF RESOURCES BY RIVER AUTHORITY AREAS

TABLE G

RIVER AUTHORITY	EFFECTIVE DEFICIENCIES to nearest 5 m.g.d.						NEW RESOURCES to nearest 5 m.g.d.			Balance of Resources at 2001 m.g.d.	
	Public Water Supply		Direct abstraction by industry (including Agriculture)		Total		Isolated Sources	Regulated Rivers	Total		
	1981	2001	1981	2001	1981	2001				+	–
Northumbrian	45	165	20	40	65	205	15	500	515	310	–
Yorkshire Ouse and Hull	55	190	–	–	55	190	25	400	425	235[1]	–
Dee and Clwyd	10	25	15	30	25	55	–	150	150	95[2]	–
Mersey and Weaver	65	225	5	15	70	240	60	–	60	–	180[1]
Lancashire	40	105	5	20	45	125	10	750	760	635[2]	–
Cumberland	20	50	–	–	20	50	15	450	465	415[2]	–
TOTAL	235	760	45	105	280	865	125	2,250	2,375	1,690	180
Humberside/Lincolnshire	30	100	–	–	30	100	–	–	–	–	–
TOTALS	265	860	45	105	310	965	125	2,250	2,375	1,690	180

1. Major imports existing or authorised, nearest 5 m.g.d.:

Yorkshire Ouse and Hull	*25 m.g.d.*	*)Including 70 m.g.d. from Severn and Trent*
Mersey and Weaver	*270 "*	*) R.A. areas*

2. Major exports existing or authorised, nearest 5 m.g.d.:

Dee and Clwyd	*95 m.g.d.*
Cumberland	*120 "*
Lancashire	*10 "*

77. The relationship between resources and demands in each of the demand districts is shown in Diagrams 1-13 on the assumption that transfers will be effected and isolated sources developed as envisaged. To the extent that these transfers are not effected, nor isolated sources developed, the interim position may be worse than we have assumed but the overall comparisons of long term strategy are unlikely to be affected.

78. For the purposes of planning regional programmes of development and estimating their costs, net deficiencies in the thirteen demand districts have been rounded off to the nearest 5 m.g.d. as in the table below.

TABLE H

Demand District	Deficiency	(m.g.d.)
	1981	2001
Newcastle	15	55
Sunderland	15	40
Teesside	20	100
Hull/Humberside[1]	35	120
West Riding South	20	80
West Riding North	15	65
Flint/Denbigh	15	35
Chester	30	80
Liverpool	-	55
Manchester	5	75
Preston	15	45
Fylde	15	50
Cumberland	15	40
Totals	215	840

79. In Chapter 7 we describe alternative long term strategies for meeting these needs, many of them containing common elements up to 1981. A choice of strategy, which will determine the pattern of development post 1981, may not be made until 1971 after the barrage investigations are completed. Meanwhile, decisions will have to be made on the development of some new sources for districts in which deficiencies are expected in the 1970's. Some ways in which the short-term deficiencies might be met were indicated in the Interim Report; two of the developments - Windermere/Ullswater and Cow Green - have since been authorised. In the following paragraphs we indicate further developments which, in our view, would least prejudice the choice of long term strategy.

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[1] *Includes allowances for Humberside/North Lincolnshire of 30 m.g.d. in 1981 and 100 m.g.d. in 2001.*

Developments in the Next Decade

80. **Newcastle District**
Sunderland "
Teesside "
The Teesside district will be in deficiency until Cow Green Reservoir has been completed; thereafter the needs of these three districts will be covered by existing and authorised sources until 1973. Certain expedients described in paragraphs 48, 49 and 51 of the Interim Report would enable this period to be extended until 1977-79 in all three districts so far as public water supply needs are concerned but industrial needs are likely to bring the critical date forward to 1975 on Teesside. It is considered, therefore, that we should plan for the inauguration of major new works for Northumbria by 1975. The most urgent item will probably be a first stage of the north-south aqueduct linking the Tyne, Wear and Tees referred to in paragraph 51 of the Interim Report, to be followed by the remainder of the aqueduct together with a major new source.

81. Our analyses indicate that one scheme regulating the Tyne to serve Newcastle, Sunderland and Teesside would probably provide the most economic solution and to meet all deficiencies in these areas up to 1981 a source of about 50 m.g.d. would be required. A first stage of the development of a reservoir at Otterstone appears to be the most economic choice from the sites we have listed outside National Parks[1]. However, a site in the Cumberland River Authority area on the River Irthing - the western boundary of the Northumberland National Park - could also be used to regulate the River Tyne; this is a cheaper alternative which may well be equally or more acceptable. Both of these alternatives should be investigated without delay by the river authorities concerned.

82. **Hull/Humberside District**
West Riding South "
Demands in the rural areas of the Hull/Humberside District are assumed to be met from local sources. Hull will be deficient in 1969 and there will be a shortfall of reliable yield until a new source is commissioned. Deficiencies in North Lincolnshire (including allowances for Humberside new town) are estimated to amount to 43 m.g.d. in 1981 of which 13 m.g.d. may be met by local developments. It is not yet clear whether the residual deficiency of 30 m.g.d. in 1981 can best be met from resources in the north or from the River Trent. Demands in the Sheffield area will exceed authorised resources in 1971 and the net deficiency will amount to 20 m.g.d. in 1981.

83. If the present proposals to construct a new regulating reservoir at Farndale, in conjunction with a tidal sluice at the mouth of the River Derwent, are successfully implemented this scheme could provide for the needs of Hull/Humberside (including North Lincolnshire and new town) and West Riding South until about 1979. If the North Lincolnshire/new town demands are met from elsewhere Farndale would provide for the needs of Hull and West Riding South until about 1984.

84. **West Riding North District** The resources balance of this district shown in Diagram 5 is based upon the assumption that with one or two exceptions surpluses of individual undertakings can be transferred to offset deficiencies elsewhere. In addition to the strengthening of some existing links this assumption would require the establishment of a new bulk supply link between Leeds and Bradford. Even with those links there will be a shortfall of reliable yield until new isolated sources are developed, the most important being Calderdale Water Board's proposed Hebden Valley reservoir which, if authorised, could not be completed before 1974. With the transfers assumed and the isolated source development envisaged the district will again become deficient in 1975.

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[1] *Although preliminary investigations indicate that the best location for a dam falls just within the National Park boundary an alternative site upstream would avoid any incursion into the National Park.*

85. The possibilities for this district over the next decade are -

1. Use of existing storage in Leeds' Washburn valley reservoirs to balance abstractions from the River Wharfe: net gain in yield 6 m.g.d.
2. Development of the Grimwith reservoir site proposed by Bradford.
3. Use of part of Farndale surplus via Leeds' existing link with the River Derwent.

The change in use of the Washburn valley reservoirs is a desirable development and should be implemented. A limited contribution from Farndale may also be available for a time depending upon other demands on the River Derwent. By themselves, however, these could only meet increasing demands for about four years and they would not be wholly effective without the new bulk supply link between Leeds and Bradford.

86. The proposed reservoir at Grimwith has been excluded from the majority of our programmes in Chapter 7 because they have been selected (with the exception of Farndale) from sources outside the National Parks. A free selection would always have included Grimwith in the optimum economic solution even presupposing the prior development of Farndale. It may well be that the Grimwith scheme, which involves the enlargement of an existing reservoir, will be acceptable notwithstanding its location in the National Park. We consider therefore that the proposals for Grimwith should be pursued but that development if sanctioned should take advantage of the full economic potential of the site i.e. to a capacity of about 4,300 m.g. and a yield of 21 m.g.d.

87. The Washburn and Grimwith developments, in addition to the isolated sources, would provide for the needs of the West Riding North until the mid-1980's. The timing of Grimwith would be dependent upon the economics of the Leeds-Bradford link, and the viability of this link would in turn be dependent upon decisions about Grimwith since its usefulness would be limited once these two undertakings were both served by schemes (such as Grimwith) for regulation of the River Wharfe. Apart from its value in a regional distribution system, which it is difficult to quantify, its cost should therefore be weighed against possible savings in deferment of capital expenditure on Grimwith. We have been unable to pursue the detailed investigations necessary for this assessment but consider that they should be pursued by the river authority and the undertakings concerned.

88. **Flint/Denbigh District** **Chester** " The bulk of the Flint/Denbigh deficiency at 1981 is estimated to arise within the area of the Central Flintshire Water Board either as growth in demand on the public water supply or as an increase in direct industrial demand along the Flintshire coast of the Dee estuary. Demands already exceed authorised resources, and deficiencies are being met by increasing bulk supplies from the Wirral Water Board to the Central Flintshire Water Board. Overall economy of supply could best be served by increasing transfer of water from the Wirral Water Board's Alwen reservoir to the Central Flintshire Water Board, and the consequential transfer of Wirral's demand from Alwen to the River Dee. This transfer together with development of isolated sources would enable demands to be

met until 1972. Thereafter development of the aquifer in the Vale of Clwyd to regulate the river flow could provide about 3 m.g.d. of the estimated deficiency of 15 m.g.d. at 1981 i.e. it might meet needs until 1974.

89. After allowing for the suggested transfer of Alwen water to Central Flintshire, the subsequent temporary re-allocation of abstraction rights from the Dee and the development of isolated sources, deficiencies in the Chester District arise in 1974 and amount to 30 m.g.d. by 1981. It has been estimated that the existing storage at Bala Lake and Llyn Celyn may sustain an additional yield of about 13 m.g.d. If this estimate is confirmed by the investigations now in hand (Dee regulation research project) a major new source will be required by 1977.

90. For the Flint/Denbigh and Chester Districts a reservoir at Brenig which could be used to regulate the Clwyd and the Dee appears to be the best choice to follow the above short term expedients and we recommend that this site should be investigated by the Dee & Clwyd River Authority. This reservoir would have only a small catchment area but it could be operated effectively in conjunction with Bala Lake and Llyn Celyn, whose catchments are comparatively under-reservoired. Although it might be possible to pipe spare Dee water from the Chester District into Flintshire for a year or two pending completion of such a reservoir, the reservoir is likely to be needed at the earliest practicable date and investigations should be pursued with urgency.

91. **Liverpool District** Deficiencies arise in 1978 and amount to 10 m.g.d. at 1981. If the suggested developments of isolated sources in this district prove to be practicable no other action would appear to be necessary in advance of the long term decisions. In addition, if the reservoir at Brenig, referred to above, is developed to its full capacity in the mid-seventies additional supplies could be made available to Liverpool from the River Dee. With an estimated yield of 70 m.g.d. Brenig could meet the combined deficiencies of Flint/Denbigh, Chester and Liverpool until about 1985.

92. **Manchester District** The yield of the Ullswater/Windermere scheme as authorised will be somewhat less than that envisaged in the Interim Report and the short term balance of demands and resources in this district is also subject to the completion dates of various stages of these works.

93. The safe yield of the Manchester District's resources including the Ullswater/Windermere scheme is now estimated to be 238 m.g.d. and Diagram 10 based upon the most recent estimates of construction time shows the dates by which the additional quantities are now expected to become available and the subsequent deficiency date. Allowance has been made in the diagram for the addition of 3 m.g.d. of yield in 1976 resulting from a contemplated improvement in the aqueduct capacity from Haweswater. Thereafter the district becomes deficient again in 1977 but the development of isolated sources is estimated to be capable of meeting demands until 1981.

94. Diagram 10 also indicates that during the construction period leading up to the full development of the Ullswater/Winderemere scheme Manchester District will have no significant surplus for deployment elsewhere. This changes the situation described in the Interim Report where it was assumed that Manchester would have a surplus available in 1971 for deployment within what was described as the West Pennine Zone and there are consequently repercussions on the dates at which Preston and Fylde districts will now need to develop new supplies.

95. **Preston District** As shown in Diagrams 11 and 12 these districts become
Fylde " deficient in 1971 and will each need a further 15 m.g.d. by 1981. Deficiencies can be met by changes in use of existing storage and the use of underground storage in conjunction with suitable river abstractions. Fylde and Preston's existing storage together with storage developed underground in the Fylde area has been estimated to provide an additional yield of 17 m.g.d. if used to balance river abstractions (Lancashire River Authority Schedules II, Lune, Wyre and Ribble). Similar use of Liverpool Corporation's Rivington storage could provide a further 9 m.g.d. and together these developments would provide for the needs of the two districts until about 1980. If abstractions from the River Lune formed a major part of an integrated conjunctive use system additional yields could be obtained by constructing a tidal barrier in the lower reaches of that river, if this proved feasible.

96. A further recent development not included in our schedules of resources is the suggestion, now being investigated, of raising the embankment at Stocks reservoir thus providing some 1000 m.g. of additional storage. Used in conjunction with river abstractions this additional storage would provide a further additional yield of about 6 m.g.d.

97. The storage potential of the underground aquifer, the feasibility of a tidal barrier on the Lune and the most effective way of developing the integrated system including the progressive use of existing reservoir storage to balance river abstractions are all matters requiring detailed investigation. Initial requirements are, however, urgent and arrangements for the first phase of development should be considered by the Lancashire River Authority without delay.

98. **Cumberland District** The authorised resources of the South Cumberland Water Board now include an estimated increase in yield of 6 m.g.d. from Ennerdale without changing the level of the lake. The district first becomes deficient in 1969/70 and development of isolated sources (groundwater in West Cumberland and further control of Ennerdale) could meet demands until 1972. The subsequent deficiency of 15 m.g.d. at 1981 will have to be met from new sources of supply.

99. Apart from these deficiencies in supplies the river authority is faced with the situation that abstractions from the River Derwent under licences of right already create unacceptable low flow conditions in the lower reaches of the river in a dry year. The development of surface storage in the River Derwent catchment is the logical solution to both problems and the river authority is investigating means of augmenting river flows by the use of controlled storage in Bassenthwaite Lake or by construction of regulating reservoirs in tributary valleys. Both of these ways of regulating the river flow could be combined with a tidal weir at Workington which would minimise residual flow requirements.

100. Limited control of Bassenthwaite Lake has so far been envisaged as a means of restoring the present unsatisfactory conditions in the river. Subject to the final conclusions of the consulting engineers a reservoir on the River Marron at Ullock appears to be the most economic choice outside the Lake District National Park for providing new regulated yields to supply. This reservoir could provide in conjunction with a tidal barrier a yield of over 100 m.g.d. Whilst construction could possibly be staged, major capital expenditure would be involved, much of which would be unproductive until the full yield is taken up.

101. An alternative would be more extensive control of Bassenthwaite to meet deficiencies over the next decade followed by the use of part of Thirlmere storage to regulate the River Derwent. In this way the resources available to West Cumberland could be built up gradually and the progressive loss to

Manchester (18 m.g.d. by 2001) made good from other sources which will in any case be required for supplies in that area after 1980. This alternative deserves more detailed consideration before a decision is taken to construct the Marron reservoir.

Summary

102. The proposals in paragraphs 80 to 101, if proved feasible on detailed investigation, would suffice to safeguard supplies over the next decade until long term strategic plans can be implemented. However, they should not be assumed to preclude the possibility of alternative courses of action during this period. In the course of the surveys which will be carried out by the river authorities under Section 14 of the Water Resources Act local requirements will be considered in much greater detail than has been possible in this report and river authorities may well suggest alternative local solutions. Our main concern in this section of the report has been to indicate some ways in which a breathing space may be secured for the deliberate consideration of long term plans.

103. We referred in paragraph 15 to Manchester's bulk supply obligations to other undertakings. These bulk supplies at present aggregate 28 m.g.d. but, subject to authorisation by the Minister of Housing & Local Government, considerably greater bulk supplies could in future be claimed by reserving authorities. Our allocation of future demands to thirteen demand districts, however, does not contemplate any extension of these relationships as between an undertaking in one demand district and those in another and regard must be had to this in considering future applications for bulk supplies.

CHAPTER 6: THE USE OF LAND FOR RESERVOIRS

Amenity and Recreation

104. In this crowded island land is precious, and it is proper that before turning over substantial areas to water storage, or any other new use, careful thought should be given to what may be lost. Where new reservoirs are contemplated the main social issues will usually be either the dispossession of local farming communities and the losses to agriculture and forestry or the coming of a major change in a landscape valued by a wider public for its beauty and solitude. In comparing two or more sites these considerations may be in direct conflict. At northern reservoir sites the intrusion of engineering works in a more or less wild landscape has usually been the more prominent issue.

105. We wholly accept the argument that it would be profitless to provide water or other services at the cost of completely despoiling our environment. This is perhaps more widely accepted now than it was a few generations ago or than it is in countries where the pressure of population is less extreme. But it would be foolish to dismiss the real conflicts of interest which arise and to ignore the views of those who find a reservoir as acceptable a feature of the countryside as the many 'intrusions' of our forbears which help to compose the scene we admire to-day. A blind defence of the status quo is likely to achieve less than a realistic but discriminating accommodation to the material and recreational needs of a growing population.

106. During the nineteenth century a water undertaking which took over an upland valley or natural lake and converted it into a reservoir would usually bar public access to the reservoir and its immediate water catchment grounds. There were good reasons for this in the new awareness of the dangers of water-borne disease and in the comparative inadequacy of treatment processes. But this meant that a valley used for water supply was lost to the community at large and local people often believed that they had everything to gain and nothing to lose if they could fight off the acquisitive authority.

107. Nowadays an expanding population, expecting ever better standards of living, calls not only for greater supplies of water but for ampler means of occupying its longer leisure hours. There is an acknowledged need on the one hand for access to large areas of unspoilt moorland and fellside remote from the conurbations and, on the other, for improved facilities for active and passive outdoor recreation, for which reservoirs - especially river regulating reservoirs - can provide considerable opportunities.

108. Most water undertakings are ready to play their part in meeting these needs. Some of them - such as Manchester Corporation, who own extensive mountain catchments in the Pennines and the Lake District - have been opening their gathering grounds increasingly to public access in recent years, and in the long run the acquisition of these lands may be seen to have contributed to rural conservation, by discouraging other forms of development and by stabilising the local economy. Others have shewn great initiative - as at Chew Lake, at Pitsford, at Llyn Celyn, at Grafham Water and at the new Derwent Reservoir - in developing their reservoirs for active recreational pursuits such as fishing, sailing and birdwatching as well as making planned provision for the needs of picnickers and motorists.

109. There is implicit here a secondary conflict, between those to whom a reservoir is more acceptable if it brings improved access to the countryside with more opportunities for active recreation and provision for the needs of the

visitors thus attracted, and those to whom it is more objectionable for these very reasons. It is not unknown that on a specific project one 'countryside' interest will seek to impose restrictions on access to the area whereas others insist on improved access as a condition of assent.

110. Thus there is a need to appraise recreational opportunities, which are difficult to quantify (Appendix VI), in relation to the even more subjective aesthetic values and to balance both against the needs of water supply. In many cases recreational opportunities obviously appeal to large numbers once they become available although when projects are at the planning stage it is the threat to natural, or at least familiar, surroundings which arouses passionate feelings of protest and active involvement.

National Parks

111. The region dealt with in this report contains an unusually high proportion of areas which call for special consideration in this respect. Six of the ten national parks lie wholly or partly within the region, as do many of the most important areas designated as 'of outstanding natural beauty'. These areas together occupy some 2,800 square miles within the region - i.e. some 55% of the designated areas as a whole and 18% of the region itself. Of the reservoir storage now serving the region a large proportion lies in the parks, which include many of the areas of most varied topography and high rainfall, and the headwaters of most of the major rivers which could be regulated to serve the north in the future rise in the parks.

112. It is inevitable, therefore, that some of the projects with most technical advantages for further storage would encroach on the parks. On the other hand those of our conservation programmes which do not include projects in the National Parks include developments in other localities which may be held in higher regard than individual sites within the parks. In saying this we do not accept that reservoirs will necessarily impair permanently the beauty of these places but we have in mind that the park areas were designated so that development within them should be considered with special care.

Agriculture

113. The interests of farming and forestry can be partly quantified in terms of land or product value and we have allowed for this in the estimated costs of schemes. There is room for argument about how this should be done but the amounts involved are in any case very small compared with the sums which are included in estimates for engineering works.

114. As with amenity considerations, however, the main factors are probably those which are more difficult to quantify - the disturbance to the rural scene, the loss of livelihood and sense of security of those earning their living from the land, and the resulting general feeling that rural interests are constantly being sacrificed to the appetites of urban civilisation. These factors must be recognised, and indeed in countries with a dense and growing population and changing technology - in agriculture, no less than in other spheres - these things are bound to happen. But the essentially psychological elements ought not to be confused with economic considerations; nor is it proper to foster the belief that the nation is squandering its productive land for what is only a transient gain.

115. To get the reservoir problem into perspective it is worth noting that most of the inland conservation programmes described later in this report would involve the submergence of about 15,000 acres of land (out of a total of some 10 million acres) i.e. 0.15% of the area of the region, to secure its water needs until the end of the century. Most of this area would be outside national parks and areas of outstanding natural beauty and would be on land of relatively poor agricultural value. These programmes would roughly double the present water storage in the region of some 150,000 million gallons, about two-thirds of which is on sites in the parks or in areas of outstanding natural beauty.

116. Clearly, if demands continue to grow the time will come when increasing storage of fresh water on land will have to give way to other methods of augmenting our resources, although the reservoirs then existing will probably continue indefinitely to contribute their share of our needs. The time is far distant when more than a fraction of one per cent of our land surface could be needed for this purpose and it is likely that when that time comes these techniques will no longer provide an economic answer. For the present, however, storage of natural fresh water is overwhelmingly the most economic way, and to opt instead for desalting sea water would place a heavy economic burden on this and perhaps on the next generation[1]. This is the answer to the question: 'if sometime, why not now?'.

117. Although the total area of land needed is comparatively small, some of the sites involved are nevertheless of great significance both to people living and working in their neighbourhood and to others, and development might have effects - not necessarily harmful - far beyond the immediate locality.

A Problem of Choice

118. We see this problem, like the problem of economic strategy referred to in the following chapters, in terms of choosing a coherent programme of development after weighing all relevant factors. All the proposals have disadvantages from some point of view and the best answer will not be found by arguing the merits of schemes piecemeal whilst questions of comparative merit and overall economics go by default. We have therefore tried to assemble a comprehensive list of possible schemes, limited only by an overall 'ceiling' of development in each major river basin (Chapter 4, paragraph 56). In applying this limit we have eliminated the more uneconomic developments including some sites near the centre of the Lake District National Park.

119. For reasons given in Appendix VI we have not attempted to measure the differences in recreational value between one potential reservoir and another. Nor have we presumed to assess the beauty of any site or the contribution it now makes to the lives either of the local community or of visitors. But we have tried to present our data so that the cost of including or excluding any project, as an element in an integrated system of resources, can be demonstrated.

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[1] *Details of latest costs estimate have been reviewed in W R.A. Technical Paper No.60, 1967.*

CHAPTER 7: COMPARISON OF REGIONAL CONSERVATION PROGRAMMES AND COSTS

The General Problem

120. The resources which could be made available by 'regional storage' (including estuary storage) are described in Chapter 4 and detailed in Appendix IX. Reference is made at the end of that chapter to the sequences of development and in Chapter 5 to the 'regional conservation programmes' into which individual projects must be assembled for effective comparison. Each of these programmes is a plan for the progressive development of source, treatment and bulk transmission works to match the assumed pattern of demand in the north from now until the end of the century. Since the potential resources described in this report far exceed estimated demand in the region to the end of the century there is a considerable field of choice in the projects to be developed during this period as well as in the sequence of their development.

121. We have sought to identify a least-cost solution in the sense of one which minimises the real cost, during the remainder of this century, of meeting the needs of the region as a whole - not necessarily one which minimises the cost to particular undertakings or at particular dates. The least-cost solution is, of course, not necessarily the best. Allowance must be made for social values which are not readily quantifiable and it would be idle to expect universal agreement on these. Other issues, such as the abstraction of river water from lowland rivers versus the use of 'direct supply' reservoirs are also the subject of controversy, even though we have tried to quantify and price some of these factors, as explained elsewhere in this report.

122. Apart from these issues the definition of least cost is by no means simple. Outlays which can be deferred into the future are less of a real burden than similar outlays now - i.e. there is a discount factor. In applying this we have a choice between comparing the costs incurred (for some increment of supply) to some terminal future date or indefinitely into the future. The development programmes have been tested by both of these criteria and against varying assumptions as to discount rate, future demand and future relative prices. Some of these points are dealt with at greater length in Appendix X.

123. For these reasons we present an array of solutions and comparisons. Much of the supporting detail will be found in Appendices VIII, IX and X but in the present chapter we describe in a very general way the approach used in analysis and the types of solution evolved.

124. Most of the reservoirs considered will be regarded by some as detrimental to amenity and by others as an addition to local amenities. Most, if not all, can be used to provide recreational benefits of one kind or another and ideally these should play their part in any accounting of benefits and costs. Because we are not able to discriminate between the value of the recreational opportunities offered by each inland reservoir, however, we have treated such benefits as a constant factor and have simply made comparisons between programmes which are subject to some general constraint - e.g. no inland storage sites, no estuary storage sites, no sites in national parks, etc. - or to none. In the case of estuary storage, however, it may well prove that opportunities for active recreation (or other incidental benefits such as traffic crossings) are much more significant and allowance may have to be made for these when overall studies of these schemes have been completed and when the time has come to review the comparative costs of programmes.

125. For conveying water from sources to each notional demand centre river courses have been used wherever possible,[1] linked by pipelines where necessary. It was considered that the available canals could not contribute significantly to water movement on a regional scale although several may have an important role locally. Solutions have been sought in terms of the requirements of the thirteen demand districts referred to in Chapter 4 and no consideration is given in this report to local distribution problems within the demand districts. Even so, the possible combinations of source works with 'destinations' in various sequences of development are almost innumerable and there are considerable difficulties in optimising the choice in terms of present value (i.e. discounted) costs.

126. Analysis was therefore done in two stages. For the first a readily available computer program was used to compare the costs at three future dates (1981, 1991 and 2001) of water conservation and bulk distribution systems which link the several regulated rivers with the thirteen notional demand centres in every possible combination and to select the 'least-cost' combination. This took account of both capital charges and running costs at these dates for conservation, treatment and bulk delivery.

127. This comprehensive comparison indicated the combinations of source rivers and demand centres which would minimise the costs of the system, say, in the year 2001, and the order of annual cost involved (about £60,000 per day or 17.5 pence per 1,000 gallons supplied in 2001). It could be adapted to show the extra cost of departing from this optimum in chosen ways - e.g. by excluding particular rivers or schemes - but it fell short of our requirements in not making allowance in the selection process for the timing of schemes and hence for the occasional burden of redundant capacity; i.e. there was no built-in discounting procedure. [The analysis and the findings are set out in greater detail in Appendix X.]

128. Because no suitable computer program was readily available to take account of this and other relevant factors - such as the value of continuity of use in the developing system - the remainder of the work was done on a series of programmes of individual conservation works and aqueducts, selected in the light of the general comparison made by computer. The selected conservation programmes have been costed by accumulating the capital outlays and running costs to be incurred as the particular system is built up and used over the period 1970-2001. Further, the necessary outlays and running costs to build up the system and use it in perpetuity have been discounted at 8% to their 1970 equivalents which have been summated to give a present (i.e. 1970) value total. The latter, which makes allowance for the reducing economic impact of deferred expenditures (see Appendix X) is in our view the appropriate sum for economic comparisons.

129. The various programmes are identified, described and illustrated in Appendix X. Selected programmes (numbered 1 to 10), which display the main elements of choice are outlined in this chapter and the costs of these are summarised in Table J at the end of the chapter, using the following definitions:-

Total Outlay: The amount which would have to be expended to build up and maintain and operate a given increment of the water resources system during the period 1970-2001.

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[1] *The direct supply solution is an exception.*

1970 Value: The amount which would have to be invested in 1970, at 8% annual interest, to enable such an increment of the water resources system to be built up over the period 1970-2001 and maintained and operated in perpetuity.

All amounts used in this report are quoted in £p i.e. in terms of the present level of prices.

Direct Supply Solution

Programme No. 1 (1970 Value £159 million)

130. In this system the thirteen demand centres would be linked with upland impounding reservoirs by pipeline - the traditional form of development for the urban centres of the north. It is an arrangement which minimises treatment problems but which usually reduces the flow of the rivers over most of their length.

131. It has been explained in Chapter 4 (Para. 69) that the total yield of the storages (other than 'isolated sources') which we have listed, when used as direct supply reservoirs, would amount to about 1,400 m.g.d. The most economical selection from these to service a direct supply system throughout the north (giving an additional 840 m.g.d. of yield) would involve development of 41 reservoirs, 25 of them in national parks or areas of outstanding natural beauty. They would occupy about 22,500 acres of land. The location of these reservoirs is shewn in Figure 1(a) and their required dates of completion in Figure 1(b) of Appendix X.

132. Some of the reservoirs itemised (including a number in national parks) could be replaced by alternatives but it would not be possible to preserve this overall 'direct supply' programme whilst eliminating all developments within national parks. Seventeen of the reservoirs involved could be eliminated by substituting two large pumped storage schemes for direct supply - Killington and enlarged Haweswater - at an additional 1970 value of, say, £15 million.

133. Overall reliance on direct supply reservoirs is not likely to be entertained as a serious proposition and, indeed, many water supply undertakings already practise abstraction from the lower reaches of regulated rivers followed only by tactical storage. It is of interest, however, to show the relative economy of river regulation techniques, apart from the benefits accruing to other river users. A programme combining direct supplies for some users with regulated river supplies for others is presented below (Programme No. 4).

River Regulation Systems

134. These are systems which will provide new increments of supply (other than those from 'isolated sources') from abstraction points on the lower reaches of major rivers regulated by inland storage or from pumped storage reservoirs fed from these abstraction points. The regulating storage considered includes a number of existing direct supply reservoirs adapted for the purpose and some storage made available by controlled pumping of underground aquifers.

135. In the following paragraphs the principal conservation works involved in each programme are listed, together with some important alternatives. Where comprehensive lists are not given the principal items are identified and

the various supplementary works will be found in the appropriate figure in Appendix X. The discounted costs ('1970 values') quoted in this chapter cover the regional programmes comprehensively: i.e. they include all future costs other than those of 'isolated sources' and distribution costs within demand districts.

Programme No. 2 (1970 Value £121 million)

136. A free selection from the storages scheduled gives a least-cost programme including the modified use of seven existing reservoirs and the construction of seventeen new reservoirs as follows:-

Change of Use[1]:-

Ref. No.	Reservoir	Yield	Date[2]	Conjunctive Use With
Y.1	Gouthwaite	8	1971	River Ouse
L.14 L.23 L.26	Stocks	15	1971 1972 1975	Lancashire Rivers (together with groundwater)
N.11	Derwent (Northumbrian)	11	1973	River Wear
D4 D5	Llyn Celyn	13	1973	River Dee (Improved Regulation)
Y.11	Washburn	6	1974	River Wharfe
L.25	Longridge	2	1974	River Ribble
L.31	Rivington	9	1976	River Ribble

New Schemes:-

Ref. No.	Site	Yield	Date[2]	National Park or Area of Outstanding Natural Beauty
D.2	Tube Wells (River Clwyd)	3	1971	
C.7	Wastwater (level regulation)	6	1974	Lake District
Y.12	Grimwith[3]	21	1975	Yorkshire Dales
C.1	Cocker	34	1976	Lake District
D.1	Brenig	80	1976	
N.4	Irthing	73	1977	Northumberland
Y.2	New Gouthwaite	24	1977	
L.27	Stock Beck	4	1979	
Y.3	Bishopdale	45	1980	Yorkshire Dales
L.30	Stankhill Beck	7	1980	
L.11	Roeburn	28	1981	Forest of Bowland
L.28	Hellifield	89	1984	
N.12	Witton-le-Wear	91	1985	
L.12	Dee (Lune)	76	1991	Yorkshire Dales
Y.4	Arkle Beck	44	1994	" "
D.6	Twrch	19	1995	Snowdonia
N.18	Middleton	79	1996	
L.29	Upper Hodder	53	1999	Forest of Bowland

The two developments in the Lake District National Park could probably be replaced by the Marron Reservoir without increasing the 1970 value of £121 million by more than about 1% (say, £1 million) or by the use of Thirlmere for regulation of the R.Derwent (Cumberland) which would decrease it by about 1%.

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1. *These items will also apply to all subsequent programmes.*

2. *Refers to date required in service.*

3. *Under Programme No.2 Grimwith Reservoir would be partially used to regulate the R.Wharfe to meet the needs of Sheffield and Hull in the mid-1970's. This may pose unacceptable problems to the undertakings concerned. The addition of Farndale to the programme would eliminate this need and would also eliminate the need for the development of New Gouthwaite in 1978 but at an increased programme value of £124 million.*

Programme No. 3 (1970 Value £132 million)

137. The Water Resources Board recommended in their Interim Report that an immediate start should be made on a reservoir at Farndale to regulate the Yorkshire Derwent and our remaining programmes take Farndale as their starting point. If, following this development all other works within national parks were proscribed the minimum cost solution would have a 1970 value about £11 million greater than that of Programme No. 2 and would involve the changes of use listed for Programme No. 2 together with the Clwyd Tube Wells and fifteen new reservoirs as follows:-

Ref. No.	Site	Yield	Date
Y.13	Farndale	47	1975
C.2	Marron	40	1975
D.1	Brenig	80	1976
N.5A	Otterstone (Stage I)	73	1977
L.27	Stock Beck	4	1979
L.30	Stankhill Beck	6	1980
Y.2	New Gouthwaite	24	1980
L.28	Hellifield	89	1981
Y.5	Birkby Nab	30	1983
N.12	Witton-le-Wear	91	1985
L.15	Flake Bridge	28	1990
N.5A	Otterstone (Stage II)	90	1991
L.16	Birk Beck	9	1993
D.3	Upper Clwyd	10	1995
N.18	Middleton	80	1996
L.5	Mint	17	1999

Programme No. 4 (1970 Value £137 million)

138. Certain areas of the north have long been accustomed to a piped supply of soft water from upland reservoirs and notwithstanding our conclusions as to the optimum economic development they may set considerable store on the continuation of such a supply. Among those areas which now use upland supplies exclusively and might under some of the above arrangements be switched to a regulated river supply the most notable is the Manchester conurbation. We have therefore costed a mixed system which would provide for a direct supply to Manchester (i.e. the Manchester 'demand district') whilst using regulated rivers to supply other parts of the region. The major items would be as in Programme No. 3 except that the introduction of Killington into the programme, supplying Manchester direct, dispenses with the need for Flake Bridge, Birk Beck and Mint.

Programme No. 5 (1970 Value £136 million)

139. Consideration has also been given to a restricted list of large reservoir sites since it may be worthwhile to incur somewhat greater costs in order to limit disturbance to fewer localities. Seven or eight such reservoirs together with the changes of use listed in Programme No. 2, the Clwyd Tube Wells and Stock Beck would meet requirements as follows:-

Ref. No.	Site	Yield m.g.d.	Inaugural date	Alternatives	Yield m.g.d.	Inaugural date	Remarks
Y.13	Farndale	47	1975	-	-	-	North York Moors National Park.
C.2	Marron	40	1975	Thirlmere(1)	0–40	1975–2001	(1) Use of existing reservoir for gradually increasing regulation of R.Derwent; loss to Manchester replaced by earlier completion of Hellifield and(ultimately) increased yield from Killington.
D.1	Brenig	80	1976				Construction may be staged.
N.5A	Otterstone	210	1977				Construction may be staged.
L.28	Hellifield	89	1980				
L.3	Killington	134	1990	Haweswater(2)	Up to 200		Yield figures include Lune tidal barrier. (2) New reservoir submerging existing one in Lake District National Park.
N.12	Witton-le-Wear	89	1995	Bishopdale(3)	114		(3) In Yorkshire Dales National Park; construction may be staged.
N.18	Middleton	80	1998				

140. If the listed alternative reservoirs were chosen the overall cost would not change significantly but the optimum order of development would probably be changed. According to our preliminary estimates of yield, however, Bishopdale would not be an adequate replacement for Middleton and Witton unless at the same time Killington was developed to a larger capacity or was replaced by Haweswater.

Estuary Schemes

141. Preliminary reports have been made by consulting engineers on three estuarine areas bordering the Irish Sea - Solway Firth, Morecambe Bay and the Dee Estuary. Investigations are continuing on the latter two. At Solway a barrage to impound fresh water has been considered and in the Dee a system of pumped storage lagoons. Both arrangements are under consideration at Morecambe. The preliminary reports indicate that the combined yield for these sites might reach about 1,400 m.g.d., which would more than suffice to cover the additional needs of the north during this century.

142. Estimates of yield and cost are provisional pending completion of studies and investigations on site but this is also true of most of the inland sites referred to in this report. However, because of the more unusual engineering problems of estuary sites and the probably more extensive effects of these projects on other interests the preliminary assessments of these schemes should be treated with particular caution. On the other hand the offsetting benefits in estuaries may prove to be considerable.

In the programmes which follow estuary storage has been used to displace post-1981 inland schemes. All schemes in national parks and areas of outstanding natural beauty (excepting Farndale) have been eliminated and the estuary schemes have been supplemented by other inland schemes chosen to minimise costs.

Programme No. 6 (1970 Value £145 million)

143. Using the cost estimates put forward in the preliminary reports we have concluded that a least cost solution confined (post 1981) to the estuary schemes would absorb

200 m.g.d. from Dee
250 m.g.d. from Morecambe
170 m.g.d. from Solway

together with 220 m.g.d. from inland sources required before 1981, of which the principal items would be:-

Ref. No.	Site	Yield	Date	Remarks
Y.13	Farndale	47	1975	
C.2	Marron	15	1975	
D.1	Brenig	29	1976	
N.5A	Otterstone	39	1977	or Irthing (partly within Northumberland National Park)

This programme would of course limit the use of inland areas for reservoirs to a minimum (some 3,500 acres apart from isolated sources).

Programme No. 7 (1970 Value £146 million)

144. The development of both Morecambe and Solway would suffice to cover post-1981 deficiencies if Dee were not to be developed or if its output was required elsewhere.

Needs would be met from:-

Morecambe	450 m.g.d.
Solway	170 m.g.d.

together with main pre-1981 items as in Programme No. 6 (inland area 3,500 acres).

Combined Estuary/Inland Schemes

145. If estuary sites are to be used to meet a part of the post-1981 deficiency but inland reservoirs are preferred for those demand centres more remote from the estuaries, various combinations of estuary and inland sites may be considered.

Programme No. 8 (1970 Value £141 million)

146. One of these combinations would incorporate the Dee and Morecambe estuary schemes together with the principal inland reservoirs all at yields given in Programme No. 6, with the exceptions of Otterstone and Marron reservoirs which would be developed to 184 and 40 m.g.d. respectively, so eliminating the need for Solway. Various combinations of Irthing, Witton-le-Wear and Middleton would provide alternatives to Otterstone.

Programme No. 9 (1970 Value £143 million)

147. This would be almost identical with Programme No. 8 excepting that Morecambe would be developed to a yield of 450 m.g.d. and Dee would not be required.

Programme No. 10 (1970 Value £132 million)

148. If the Dee estuary were to be developed to a capacity of 260 m.g.d.[1] but other estuarial developments were eliminated the major inland reservoirs in a least cost programme would be as follows:-

Ref. No.	Site	Yield	Date	Remarks
Y.13	Farndale	47	1975	
C.2	Marron	40	1975	
D.1	Brenig	29	1976	
N.5A	Otterstone	74	1977	Irthing as the alternative
Y.2	New Gouthwaite	24	1980	
Y.5	Birkby Nab	30	1983	
N.12	Witton-le-Wear	91	1985	Larger Otterstone as the alternative
L.28	Hellifield	89	1991	
N.18	Middleton	80	1996	

Deletion of Humberside/Lincolnshire Demand

149. All the above basic programmes are designed to meet deficiencies amounting to 840 m.g.d. in the year 2001 and including 100 m.g.d. at that date and 30 m.g.d. in 1981 for a new Humberside town and for north Lincolnshire. In the following reduced programmes Nos. 11, 12 and 13 these export items have been eliminated, the final output therefore being 740 m.g.d.

Programme No. 11 is a variant of Basic Programme No. 3 (1970 Value £114 million)

Programme No. 12 " " " " " No. 5 (1970 Value £116 million)

Programme No. 13 " " " " " No. 9 (1970 Value £124 million)

150. In programmes Nos. 11 and 12 one of the major reservoirs in the north east (Middleton or Witton) would be deleted from the corresponding basic programme whilst in Programme No. 13 the yield from Morecambe would be reduced to about 300 m.g.d. In each case the 1970 value of the basic programme has been reduced by about £20 million or 14% and we consider that the relative merits of all the basic programme types would remain the same for these reduced programmes.

Additional Export Demands

151. In Programmes Nos. 14, 15, 16 and 17 (being variants on Programmes Nos. 2, 3, 5 and 9) the Humberside demand has been reinstated and in addition an arbitrary export demand has been imposed on the west coast. This has been met by construction of Dee Estuary storage, so releasing Vyrnwy Reservoir and existing and new storage on the Upper Dee to meet demands on the River Severn. Allowance has been made for piping the Dee water from a point near Chirk into a tributary of the Severn; if it proved, however, that abstraction of these amounts from the River Dee was not permissible upstream of existing major abstraction points near Chester, the delivered costs of these exports would rise by a few pence per thousand gallons.

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[1] *Since a limited development of Brenig to yield only 29 m.g.d. is postulated in this programme the yield of Dee Estuary has been put at 260 m.g.d.*

152. It is emphasised that this western export has been postulated simply to demonstrate the conditions under which the north of the country could assist in meeting the needs of areas further south. It has not been considered in relation to specific demands in other regions nor is it intended in any way to prejudice the question of how such demands are to be met.

153. For simplicity the storage made available in this way (53,000 million gallons gross: 47,000 m.g. effective) has been assumed to sustain a Severn abstraction of 275 m.g.d., in accordance with the relationship adopted for the northern rivers, and the hypothetical West Midlands demand has been assumed to arise in 1981 and grow to 275 m.g.d. by 2001. To permit comparison with other costs the costs given cover treatment of the water and delivery from the Severn as far as Birmingham. The 1970 values (of programmes with an ultimate yield of 1,115 m.g.d.) exceed those of the corresponding basic programmes by about £35 million (25% to 30%).

Programme No. 18 is a development of Programme No. 9 by addition of the following projects:-

154.	Dee Estuary	Enabling Upper Dee sources to be diverted to West Midlands
	Brenig Stage II	For West Midlands
	Hellifield) Killington) Middleton)	Enabling Morecambe yield to be diverted to West Midlands

This programme would have an ultimate overall yield of 1,450 m.g.d., enabling about 600 m.g.d. to be exported to the West Midlands in 2001 (in addition to 100 m.g.d. exported on the east coast). The western export is assumed to meet a demand arising in 1981 and growing to 600 m.g.d. by 2001.

155. The 1970 value of Programme No. 18 (including treatment of export and delivery to Birmingham or roughly equivalent points such as River Trent or River Thames) would be of the order of £240 million. A similar Programme in which Solway would take the place of Otterstone, Middleton and the greater part of the Marron yield - i.e. a development of Programme No. 7 - (as shown in Table J) would cost slightly more.

156. Programmes Nos. 17 and 18 indicate that by development of the Dee Estuary and Morecambe Bay the needs of the north could be met and large additional amounts made available for export to areas further south. The costs involved are given in Table J at the end of this Chapter. However, comparisons with the costs of the basic and reduced programmes can only be made on the basis of unit costs.

Unit Costs of Water

157. Economic comparison of the basic programmes (for 840 m.g.d. ultimate yield) may readily be made in terms of their 1970 value since they would all deliver similar amounts of water. To compare the economics of programmes of differing size (740, 840, 1,115, 1,450 m.g.d.), however, some reference must be made to unit costs (i.e. costs per quantity supplied). These can be conveniently defined here in two ways [1]:-

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[1] *It should be noted that neither of these definitions coincides with unit cost as usually quoted for a single project.*

Mean unit cost: Total outlay divided by total amount supplied during the period 1970 to 2001 (4,310,000 million gallons for basic programmes).

1970 unit value[1]: 1970 value divided by amount supplied to perpetuity, discounted at 8% p.a. (1,249,000 million gallons for basic programmes). This is the ratio between two discounted amounts, viz:

(i) all future costs discounted at 8% p.a. to their 1970 value;
(ii) all amounts of water to be supplied in the future 'discounted' to 1970 by an exactly parallel arithmetical procedure.

158. Mean unit costs for the basic and reduced Programmes Nos. 2-13 range from 19 to 23 pence/thousand gallons, the differences between the basic and reduced programmes not being particularly significant. For the direct supply Programme No. 1 the figure is 24 pence/thousand gallons. 1970 unit values range from 23 to 28 pence/thousand gallons for Programmes Nos. 2-13 (31 for Programme No. 1).

159. Some idea of the impact of an increasing scale of development on average costs may be obtained by comparing the unit costs of water derived from Programmes Nos. 13, 8, 17 and 18, which make roughly similar demands on inland storage, as follows:-

Programme No.	Total Export (m.g.d.)	Ultimate Yield (m.g.d.)			Mean Unit Cost	1970 Unit Value
		Estuary	Inland	Total	(pence/thousand gallons)	
13	-	300	400	740	21	27
8	100[2]	450	390	840	21	27
17	375[2]	650	465	1,115	23	27
18	700[2]	870	580	1,450	28	31

160. The mean unit cost evidently rises considerably with the higher export demand although the effect on discounted price is obscured by the remoteness in time of this demand. It is not easy to put a price on the exported water itself because this will depend on the basic programme chosen for comparison. In round figures, however, the unit costs of the western export would be:-

Programme No.	W. Midlands Export Yield m.g.d.	Mean Unit Cost	1970 Unit Value
		(pence/thousand gallons)	
17	275	26	27
18	600	38	40

161. The development programmes considered in this chapter and their costs are summarised in Table J opposite.

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[1] *This is similar to the present value costs expressed in pence per thousand gallons or 'p.v.d./1,000g' as used in the Dee Crossing Study (Phase I) Report.*

[2] *Including 100 m.g.d. to North Lincolnshire.*

TABLE J

Principal Conservation Programmes

	Prog. No.	Principal Elements of Programme	Yield in 2001 m.g.d.	Land used (nearest 500 acres)[2]	Approx. % Yield from Estuaries	Programme Cost[1] (£p millions)	
						Total Outlay	1970 Value
		Direct Supply System:-					
	1	Free selection of inland reservoirs	840	22,500	-	426	159
BASIC PROGRAMMES		**River Regulation Systems:-**					
	2	Free selection of inland reservoirs	840	14,500	-	342	121
	3	Inland reservoirs outside National Parks[3]	840	14,000	-	372	132
	4	As 3 but direct supply to Manchester	840	13,500	-	381	137
	5	Eight large inland reservoirs	840	12,500	-	380	136
		Estuary Programmes:-					
	6	Three estuaries: Dee, Morecambe, Solway	840	3,500	75	402	145
	7	Two estuaries: Morecambe, Solway	840	3,500	75	421	146
		Mixed Programmes:-					
	8	Two estuaries: Dee, Morecambe } plus some major inland reservoirs	840	5,000	55	387	141
	9	One estuary: Morecambe	840	6,000	55	409	143
	10	One estuary: Dee	840	10,500	30	376	132
REDUCED PROGRAMMES		**Reduced Programmes:-**					
	11	Inland reservoirs outside National Parks[3]	740	12,500	-	317	114
	12	Seven large inland reservoirs	740	11,000	-	330	116
	13	One estuary: Morecambe (plus major inland reservoirs)	740	6,000	40	332	124
AUGMENTED PROGRAMMES		**Augmented Programmes:-**					
	14	Free selection of inland reservoirs (plus Dee Estuary)	1,115	14,500	20	477	159
	15	Inland reservoirs outside National Parks (plus Dee Estuary)[3]	1,115	14,000	20	507	168
	16	Eight large inland reservoirs (plus Dee Estuary)	1,115	12,500	20	519	170
	17	Morecambe (plus Dee Estuary) } plus major inland reservoirs	1,115	6,000	60	528	176
	18	Morecambe & Solway (plus Dee Estuary)	1,450	9,500	60	765	241

1. *Programme costs include a proportion of the total cost of schemes, including estuary schemes or stages thereof, which would provide surplus capacity at 2001 (See Appendix X, para. 18).*

2. *Excluding estuarial sites and isolated sources, the latter using about 1,500 acres and possibly including one or two sites in National Parks.*
In determining areas in the table, estimated areas at TWL have been increased by 7½ per cent to allow for marginal needs.

3. *But including Ferndale.*

CHAPTER 8 : SUMMARY AND RECOMMENDATIONS

162. We have set out to assess all water demands - public and private - in the six northern river authorities during the remainder of this century, to assess all natural fresh water resources and to compare the overall regional economy of matching the two in a variety of ways.

163. The present population of 14.8 millions uses about 900 m.g.d.[1] from the public water undertakings. This represents an average of about 62 gallons/day per capita of which 27 gallons/day is for metered trade and industrial use. The authorised resources of the present 82 undertakings aggregate about 1,150 m.g.d. For future years the following demands are expected:-

Year	Population	x	Gallons/day per capita	=	Approximate Total m.g.d.
1981	16,080,000	x	85	=	1,400
2001	19,200,000	x	100	=	1,900

164. Licenses for abstraction other than those held by public water undertakings aggregate about 7,000 m.g.d. Present gross use by these licencees (broadly speaking, industrial abstractors) probably averages about 4,000 m.g.d. After allowing for future re-use of sewage and industrial effluents we have concluded that the growing requirements of this sector can probably be met by providing extra inputs to the system of about 50 m.g.d. in 1981 and 100 m.g.d. in 2001.

165. We have concluded that the additional needs of public water undertakings and other water users may be represented by demands at thirteen 'demand centres', aggregating about 300 m.g.d. in 1981 and 1,000 m.g.d. in 2001, including allowances of 30 m.g.d. and 100 m.g.d. respectively for the possible needs of North Lincolnshire.

166. Potential new resources have been assessed in the following groups:-

(a) Isolated sources, of local significance, of which it has been assumed that a proportion amounting to 125 m.g.d. of yield will be developed.

(b) Inland storage schemes of various kinds which can be used to regulate the less industrialised northern rivers to give yields to supply aggregating about 2,250 m.g.d.

(c) Schemes for estuary storage at Dee, Morecambe and Solway which have been estimated in preliminary reports by consulting engineers to be capable of giving a combined yield of about 1,400 m.g.d.

167. We have made no analysis of schemes (a), but we have made technical assessments of schemes (b) - about 85 in all - and our aim has been to assess the characteristics and the costs of these schemes, and combinations of them, and to present the results in a simple way and one which permits reasonably fair comparison throughout the region.

168. A balance has been drawn up between total resources and needs in each river authority area. Demands have then been grouped into thirteen demand districts for the purposes of further analysis and the net new demand of each district has been determined by deducting surplus existing resources and an appropriate proportion of the yields of possible isolated sources ((a) above). These net demands remain to be met by regional resources programmes built up of sources (b) and (c) above.

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[1] *Million gallons per day.*

169. Programmes of development have been evolved in which selected regional sources are brought into service and are linked with the demand districts - by river where possible, elsewhere by pipeline - so as to meet the predicted needs. Programmes have been subject to rules governing, say, the type or number of sources and within these each programme has been optimised to give a resources network of minimum real (i.e. discounted) cost over the whole region and the entire period.

170. The costs of construction, maintenance and operation of storage works, strategic aqueducts and treatment works have been incorporated in this analysis. Overheads on the above works have been included but local authority rates have not. Nor has anything been added to cover distribution within each demand district but allowance has been made for the special treatment needs of particular districts. The effective unit cost of water (per 1,000 gallons) from the cheaper programmes would be much the same in 2001 as it is today.

171. Expenditure on such a system, together with isolated sources, is estimated to total £380 to £465 million between now and the end of the century, depending on the programme adopted. Programmes which would avoid developments (other than Farndale) in national parks or which would concentrate all strategic development in seven or eight large reservoirs seem likely to cost about £30 and £40 million above the minimum, respectively.

172. The costs of programmes which incorporate estuary storage after 1981 also seem likely to exceed that of the minimum cost programme by upwards of £30 million depending upon the yields and combinations involved. The estuary yields covered in these programmes represent between a third and three-quarters of the overall requirements of the region. The problems and costs of estuary works are the subject of further studies, however, as are the values of offsetting benefits, and these comparisons should be treated with caution.

173. Comparison should rest mainly on discounted costs. For a few of the most distinctive programmes the costs of building up the system and operating it in perpetuity, discounted to 1970 at 8%, are as follows:-

Prog. No.	Programme	Estimated Cost		Area of Land Used[1]	
		1970 Value at present prices (£ million)	Approx. Percentage increase over minimum	Nearest 500 acres	Approx. Percentage saving on Programme No.1
1	Direct supply to all demand centres (41 new inland reservoirs)	159	32	22,500	-
2	Cheapest Programme (17 new regulating reservoirs)	121	-	14,500	35%
3	Programme commencing with Farndale reservoir but using no other sites in National Parks or Areas of Outstanding Natural Beauty (15 new regulating reservoirs)	132	8	14,000	38%
5	Programme of seven or eight major regulating reservoirs	136	12	12,500	44%
6	Programme of three estuaries (620 m.g.d.) plus inland sources (220 m.g.d.)	145	19	3,500	85%

[1] *Excluding estuarial sites and isolated sources, the latter using approximately 1,500 acres and possibly including one or two schemes in National Parks.*

174. Various sensitivity tests such as the elimination of the 'export' to North Lincolnshire which has been allowed for in our basic programmes, changes in the discount rate, change in the cost of power relative to other costs and change in geographical balance of demand, have been applied (Appendix X). The relative costs of programme types do not change significantly, however.

175. Programmes have also been developed which would permit the export of water into the West Midlands; these are intended merely to indicate ways in which the north might be able to help areas further south. Under these programmes storage in the north would be made available for the regulation of the River Severn, so enabling an extra 275 m.g.d. or, alternatively, 600 m.g.d. to be abstracted from that river. Overall expenditure on these programmes is of course considerably greater than on the basic programmes but in discounted terms the unit cost (cost per 1,000 gallons) of 275 m.g.d. of exported water is not materially different from that of the water provided by the basic programme. For the larger export quantity, it would be some 50% more than the unit cost of water from the corresponding basic programme.

176. No programme is specifically recommended for adoption. Indeed, the programmes are put forward not as cut-and-dried development plans but as reference points to chart the field of choice. Subject to the results of necessary engineering investigations - inland as well as in the estuaries - the cost differences evaluated should be weighed against the less tangible social factors which will affect choice, as well as the needs and opportunities of the adjoining region, before deciding the type of long term programme to be pursued.

177. Enough information must be obtained both about the estuaries and inland sites to take these decisions by 1971-72 although the long term strategy may not begin to take shape on the ground until about 1980. Meanwhile, we have put forward in Chapter 5 proposals - subject to detailed review by river authorities - which would enable each demand district to meet its short term needs without unduly prejudicing the form of the long term strategy.

178. Although some of the cost differences which we have indicated may seem marginal and our reflections on social considerations inconclusive it must be borne in mind that the adoption of any concerted plan of action is likely to prove a good deal more economical and easier to carry out in an orderly way than continued reliance on the separate initiatives of water undertakings and others seeking their own salvation. This economy will depend, however, on retaining flexibility within the system - in particular freedom to re-allocate raw water supplies throughout the region as circumstances demand.

179. It is desirable that the decisions referred to in paragraph 178 be taken in the light of design information at other reservoir sites comparable with that which will be available for Morecambe Bay and the Dee Estuary at the conclusion of the feasibility studies. Certain sites - principally those on which the 'large source' programme is based - would play a part in many of the possible programmes of development. On the assumption that it is desirable to keep a wide range of options open we therefore recommend that the feasibility of constructing dams at the following major sites - including site investigations where necessary - should now be established:-

Otterstone	River North Tyne:	Northumbrian R.A.
Irthing	River Irthing:	Cumberland R.A.
Witton-le-Wear	River Wear:	Northumbrian R.A.
Middleton	River Tees:	"
Bishopdale	River Ure:	Yorkshire Ouse & Hull R.A.
Arkle Beck	River Swale:	"
Birkby Nab	River Ure:	"
Brenig	River Dee:	Dee & Clwyd R.A.
Hellifield	River Ribble:	Lancashire R.A.
Borrowbeck	River Lune:	"
Killington	River Kent:	"
Marron	River Derwent:	Cumberland R.A.
Enlarged Haweswater	River Eden:	"

180. In addition certain local developments (including some listed as 'isolated schemes') will have to be pursued urgently by river authorities and water undertakings and the necessary engineering investigations should proceed without delay. These include the following:-

Northumbrian R.A.	An aqueduct to link Tyne, Wear and Tees.
Yorkshire Ouse & Hull R.A.	The economics of liaison between the Leeds and Bradford water undertakings and of relevant storage developments in the area; the possibility of developing underground storage in the chalk of the River Hull basin for regulating the flow of the river; conversion of existing Gouthwaite reservoir from compensation to regulation and the possibility of enlarging the reservoir.
Mersey & Weaver R.A.	The development of storage, either surface or underground, for use in conjunction with the Rivers Dane, Weaver, Bollin, Irwell and Tame.
Lancashire R.A.	Use of existing reservoirs and of underground storage in conjunction with suitable river abstractions, together with the possibility of constructing a tidal barrier on the River Lune. The possible use of the Lancaster Canal as a transmission link.
Cumberland R.A.	Control of Bassenthwaite Lake to provide additional supplies in addition to providing benefit to the river; in conjunction with Manchester Corporation the possibility of using part of Thirlmere storage for regulation of the River Derwent. In the short term, development of underground supplies from the St. Bees Sandstone in West Cumberland.

181. Reference has been made in Chapter 5 to certain problems which may arise from extension of the relationships which have evolved between Manchester Corporation and other water undertakings. Manchester's conservation works have hitherto been a corner-stone of water resources development in the north-west and many of the smaller undertakings have benefitted from the city's enterprise. Nevertheless the further development of rigid bulk supply reservations under the Manchester Corporation Acts might prejudice the freedom of choice between the longer term development plans we have outlined in Chapter 7 and to this extent impede the proper development and use of water resources. The time may therefore have come for a re-examination of these arrangements.

182. Reference has also been made in the report to the duties of river authorities under Section 14 of the Water Resources Act 1963 and to the functions and obligations of statutory water undertakings and it is on these bodies that the onus of carrying out recommendations based on this report will rest. If plans of the kind we have outlined are to command general assent and are to be put into effect, careful thought will have to be given to the administrative problems involved and in particular to arrangements for equitable financing both of short term and long term regional plans.

APPENDIX I

Tables of Demands and Resources, Surpluses and Deficiencies
(Statutory Water Undertakings)

Tables I include statistics for statutory water undertakings from the latest date available, i.e. for the year 1967. Map 2 shows the areas of supply of the tabulated undertakings as at 31st March 1968 and takes account of all re-groupings to that date.

NORTHUMBRIAN RIVER AUTHORITY

PUBLIC WATER SUPPLY

TABLE I

Ref. No.	Undertaking	Average daily demands m.g.			Resources m.g.d.					Apparent Overall Deficiencies (−) or Surpluses (+) on Net Resources m.g.d.			
		1967	1981	2001	1967	Authorised	Bulk Supplies +	Bulk Supplies −	Net Authorised	1981 +	1981 −	2001 +	2001 −
	Darlington C.B.C.	5.7	9.5	11.0	7.0	7.0	−	−	7.0	−	2.5	−	4.0
	Durham Co. W.B.	17.6	23.6	31.0	14.0	24.3	0.1	−	24.4	0.8	−	−	6.6
	Eden W.B. (1)	0.1	0.1	0.1	0.2	0.2	−	−	0.2	0.1	−	0.1	−
	Hartlepools W.Co.	11.1	16.0	18.6	11.0	15.0	−	−	15.0	−	1.0	−	3.6
	Newcastle & Gateshead W.Co.	41.8	61.6	94.8	44.0	47.0	5.9(2)	−	52.9	−	8.7	−	41.9
	Sunderland & South Shields W.Co.	25.5	40.4	54.2	16.7	29.1	−	0.1	29.0	−	11.4	−	25.2
	Tees Valley & Cleveland W.B.	74.3	126.6	186.2	76.2	111.2	−	−	111.2	−	15.4	−	75.0
	Tynemouth C.B.C.	8.9	14.7	20.7	6.6	6.8	4.1(2)	−	10.9	−	3.8	−	9.8
	Totals m.g.d.	185.0	292.5	416.6	175.7	240.6	10.1	0.1	250.6	0.9	42.8	0.1	166.1

NOTES: *(1) Eden W.B. appears also in the Cumberland River Authority Table I.*
(2) Bulk supplies from Coquet Water Board.

Croft & Darlington R.D.C.'s omitted as demands and resources less than 0.1 m.g.d.
Fringe area Stokesley no details available.

Table II - IMPORTS - NIL

Table III - EXPORTS - NIL

Table IV - NET DEFICIENCIES

	1981	2001
Effective deficiency to nearest 5 m.g.d.	45	165

YORKSHIRE OUSE & HULL RIVER AUTHORITY

PUBLIC WATER SUPPLY

TABLE I

Ref. No.	Undertaking	Average daily demands m.g.d.			Resources m.g.d.					Apparent Overall Deficiencies (−) or Surpluses (+) on Net Resources m.g.d.			
		1967	1981	2001	1967	Authorised	(1) Bulk Supplies +	(1) Bulk Supplies −	Net Authorised	1981 +	1981 −	2001 +	2001 −
	Barnsley C.B.C.	7.2	10.8	16.0	7.6	8.9	–	–	8.9	–	1.9	–	7.1
	Bingley U.D.C.	.8	1.1	1.3	0.2	0.2	0.5	–	0.7	–	0.4	–	0.6
	Bradford C.B.C.	20.1	25.5	32.3	23.5	28.5	–	5.4	23.1	–	2.4	–	9.2
	Calderdale W.B.	9.8	12.9	18.0	10.6	10.6	0.2	1.6	9.2	–	3.7	–	8.8
	Claro W.B.	7.0	8.2	10.4	8.7	10.3	–	–	10.3	2.1	–	–	0.1
	Craven W.B. (2)	4.9	6.2	8.0	4.1	4.9	–	–	4.9	–	1.3	–	3.1
	Doncaster & District Joint W.B. (3)	7.7	10.0	13.7	0.3	0.3	1.0	–	1.3	–	8.7	–	12.4
	East Yorks W.B.	6.0	8.9	15.0	7.6	9.3	0.2	–	9.5	0.6	–	–	5.5
	Huddersfield C.B.C.	12.5	14.2	18.9	10.2	15.5	–	–	15.5	1.3	–	–	3.4
	Kingston-upon-Hull C.B.C. (4)	23.2	34.0	44.0	26.8	26.8	–	0.1	26.7	–	7.3	–	17.3
	Leeds C.B.C.	31.2	42.0	60.0	30.6	36.2	–	0.2	36.0	–	6.0	–	24.0
	Mid Calder W.B.	8.1	8.4	10.1	4.7	4.7	1.9	–	6.6	–	1.8	–	3.5
	Northallerton & The Dales W.B.	3.1	3.8	5.0	2.7	2.7	–	–	2.7	–	1.1	–	2.3
	Norton U.D.C.	0.4	0.4	0.6	1.0	1.0	–	–	1.0	0.6	–	0.4	–
	N. Derbyshire W.B. (5)	11.0	19.5	39.5	3.0	3.0	–	–	3.0	–	16.5	–	36.5
	Oldham C.B.C. (6)	–	–	–	1.6	1.6	–	–	1.6	1.6	–	1.6	–
	Pontefract, Goole & Selby W.B. (7)	6.2	10.7	15.6	6.6	12.6	0.2	0.1	12.7	2.0	–	–	2.9
	Pudsey B.C.	1.5	2.3	2.8	–	–	1.4	–	1.4	–	0.9	–	1.4
	Rawmarsh U.D.C.	.8	0.9	0.9	–	–	0.8	–	0.8	–	0.1	–	0.1
	Rochdale C.B.C. (6)	–	–	–	1.7	1.7	–	–	1.7	1.7	–	1.7	–
	Rombalds W.B.	4.9	6.8	10.9	3.6	6.1	0.3	–	6.4	–	0.4	–	4.5
	Rotherham C.B.C.	4.2	5.8	7.2	0.7	0.7	6.7(8)	0.8	6.6	0.8	–	–	0.6
	Ryedale J.W.B.	3.8	7.0	10.0	3.9	4.3	–	–	4.3	–	2.7	–	5.7
	Scarborough B.C.	4.5	6.8	10.8	8.4	12.2	–	–	12.2	5.4	–	1.4	–
	Sheffield C.B.C. (7)	36.5	50.8	74.3	32.2	38.7	0.5(9)	7.7(8)	31.0	–	19.8	–	43.3
	Spenborough B.C.	1.2	1.5	1.6	–	–	1.2	–	1.2	–	0.3	–	0.4
	Wakefield & District W.B.	12.5	18.2	27.0	9.4	11.9	1.5	–	13.4	–	4.8	–	13.6
	Wortley R.D.C.	.2	0.3	0.4	0.2	0.2	–	–	0.2	–	0.1	–	0.2
	York W.W.Co. (10)	9.2	11.9	15.0	16.4	16.4	–	–	16.4	4.5	–	1.4	–
	Totals m.g.d.	238.5	328.9	469.3	226.3	269.3	15.9	15.9	269.3	20.6	80.2	6.5	206.5

NOTES:

(1) Assuming existing bulk supply obligations or transfers will continue.
(2) Craven W.B. appears also in the Lancashire River Authority Table I.
(3) Doncaster & District Joint W.B. figures exclude that part of the Water Board in the Trent River Authority area.
(4) Resources exclude the Farndale Reservoir scheme.
(5) N. Derbyshire W.B. appears also in the Mersey & Weaver River Authority Table I. Figures exclude that part of the Water Board in the Trent R.A. area.
(6) Oldham C.B.C. and Rochdale C.B.C. appear also in the Mersey & Weaver River Authority Table I.
(7) The entire demands for Pontefract, Goole & Selby W.B. and Sheffield C.B.C. are shown in the table although parts of these areas lie within the Trent R.A. Area.
(8) Including Rotherham's entitlement in Yorkshire Derwent Stage II as a bulk supply from Sheffield.
(9) Net Gain of 0.5 m.g.d. from N.C.B.
(10) Including the whole of Flaxton R.D.C.
Fringe areas; Stokesley no details available, Central Nottinghamshire W.B. and Flaxton R.D.C. demands within the area insignificant.

TABLE II - IMPORTS

	Average daily transfers m.g.d.	
	1981	**2001**
Doncaster and District W.B. transfer from Trent	8.0	8.0
North Derbyshire W.B. " " "	7.8	0.8
Sheffield C.B.C. " " "	10.1	10.1
Totals – m.g.d.	25.9	18.9

TABLE III - EXPORTS

	1981	**2001**
Oldham C.B.C. transfer to Mersey and Weaver	1.6	1.6
Rochdale C.B.C. " " " " "	1.7	1.7
Totals – m.g.d.	3.3	3.3

TABLE IV - EFFECTIVE DEFICIENCIES

	1981	**2001**
Effective deficiencies by deduction of imports from deficiencies in Table I – to nearest 5 m.g.d.	55	190

DEE AND CLWYD RIVER AUTHORITY

PUBLIC WATER SUPPLY

TABLE I

Ref. No.	Undertaking	Average daily demands m.g.			Resources m.g.d.					Apparent Overall Deficiencies (-) or Surpluses(+) on Net Resources m.g.d.			
		1967	1981	2001	1967	Authorised	(1) Bulk Supplies +	(1) Bulk Supplies −	Net Authorised	1981 +	1981 −	2001 +	2001 −
	Ceiriog R.D.C. (2)	0.3	0.9	1.3	0.2	0.2	—	—	0.2	—	0.7	—	1.1
	Central Flintshire W.B.	3.9	10.6	13.5	0.4	0.4	2.5	—	2.9	—	7.7	—	10.6
	Chester W.W.Co. (3)	4.3	6.9	9.4	7.5	7.5	—	0.1	7.4	0.5	—	—	2.0
	East Shropshire Water Board (2)	0.4	0.6	0.8	0.8	0.8	—	—	0.8	0.2	—	—	—
	Liverpool C.B.C. (3) (4)	—	—	—	32.0	64.0	—	—	64.0	64.0	—	64.0	—
	Maelor R.D.C. (2)	0.2	0.2	0.2	—	—	—	—	—	—	0.2	—	0.2
	Merioneth W.B. (2)	0.2	0.3	0.5	0.3	0.3	—	—	0.3	—	—	—	0.2
	Mid Cheshire W.B. (3)	0.4	0.7	1.2	8.0	8.0	—	—	8.0	7.3	—	6.8	—
	West Denbighshire & West Flintshire W.B. (2)	5.4	6.5	10.1	5.1	5.1	0.4	—	5.5	—	1.0	—	4.6
	Wirrall W.B. (3)	1.9	2.8	3.6	33.7	33.7	—	5.5(5)	27.6(6)	24.8	—	24.0	—
	Wrexham & East Denbighshire W.Co.	5.9	10.8	17.4	10.4	11.0	—	0.1	10.9	0.1	—	—	6.5
	Totals m.g.d.	22.9	40.3	58.0	98.4	131.0	2.9	5.7	127.6	96.9	9.6	94.8	25.2

NOTES:
(1) Assumes existing obligations or transfers will continue.
(2) Ceiriog R.D.C., East Shropshire W.B., Maelor R.D.C., Merioneth W.B. and West Denbighshire & West Flintshire W.B. - The areas of supply of these undertakings extend beyond the boundary of the study. The figures include only those parts of their areas within the Dee and Clwyd River Authority area.
(3) Chester W.W.Co., Liverpool C.B.C., Mid Cheshire W.B. and Wirrall W.B. appear also in the Mersey & Weaver River Authority Table I.
(4) Liverpool C.B.C. also appears in Lancashire R.A. Table I.
(5) Includes non-potable supply of 2.0 m.g.d. to John Summers and 0.8 m.g.d. potable supplies to industry off the Alwen aqueduct.
(6) Allowing reduction of 0.6 m.g.d. for ultimate abandonment of unsatisfactory borehole sources.

West Shropshire W.B. and Wrexham R.D.C. demands and resources within study area ignored.

TABLE II - IMPORTS

	Average daily transfers m.g.d.	
	1981	**2001**
Liverpool C.B.C. transfer from Severn to Maelor R.D.C.	0.2	0.2

TABLE III - EXPORTS

	1981	**2001**
Liverpool C.B.C. transfer to Mersey and Weaver	55.9	64.0
Mid Cheshire Water Board transfer to Mersey and Weaver	7.3	6.8
Wirral Water Board transfer to Mersey and Weaver	24.8	24.0
Totals – m.g.d.	88.0	94.8

TABLE IV - EFFECTIVE DEFICIENCES

	1981	**2001**
Effective deficiencies by deduction of imports from deficiencies in Table I – to nearest 5 m.g.d.	10	25

MERSEY AND WEAVER RIVER AUTHORITY

PUBLIC WATER SUPPLY

TABLE I

Ref. No.	Undertaking	Average daily demands m.g.			Resources m.g.d.					Apparent Overall Deficiencies (–) or Surpluses(+) on Net Resources m.g.d.			
		1967	1981	2001	1967	Autho-rised	(1)Bulk Supplies +	–	Net Autho-rised	1981 +	–	2001 +	–
	Ashton-under-Lyne etc. W.J.Ctee.	7.2	9.8	12.4	6.9	6.9	–	–	6.9	–	2.9	–	5.5
	Bolton C.B.C.	24.3	31.7	43.1	17.1	19.8	7.4	–	27.2	–	4.5	–	15.9
	Chester W.W.Co. (2)	0.2	0.4	0.5	0.5	0.5	–	–	0.5	0.1	–	–	–
	Heywood & Middleton W.B.	4.4	6.3	9.4	5.4	5.4	6.1	–	5.5	–	0.8	–	3.9
	Liverpool C.B.C. (3)	67.5	94.0	130.0	3.0	3.0	0.1	11.9	–8.8	–	102.8	–	138.8
	Macclesfield District W.B.	4.6	6.7	9.7	5.1	5.1	0.7	–	5.8	–	0.9	–	3.9
	Makerfield W.B. (4)	7.5	10.0	15.3	6.0	7.0	–	–	7.0	–	3.0	–	8.3
	Manchester C.B.C. (5)	96.3	134.0	176.0	24.0	24.0	–	11.6	12.4	–	121.6	–	163.6
	Mid Cheshire W.B. (2)	12.5	20.0 (35)	35.0 (60)(6)	6.0	6.0	0.5	–	6.5	–	13.5	–	28.5
	North Derbyshire W.B. (7)	0.6	0.9	1.9	0.1	0.1	–	–	0.1	–	0.8	–	1.8
	Oldham C.B.C. (7)	11.6	13.2	15.4	8.9	9.9	–	–	9.9	–	3.3	–	5.5
	Rochdale C.B.C. (7)	6.9	8.6	13.6	4.5	5.3	–	0.1	5.2	–	3.4	–	8.4
	Runcorn District W.B.	4.5	9.3	10.5	–	–	6.0	–	6.0	–	3.3	–	4.5
	Staffs. Potteries W.B.	0.8	1.3	1.9	1.5	3.0	–	–	3.0	1.7	–	1.1	–
	St. Helens C.B.C.	10.0	13.2	17.1	5.5	7.8	4.4	0.1	12.1	–	1.1	–	5.0
	Stockport & District W.B.	16.3	22.0	26.2	12.3	15.0	4.1	0.7	18.4	–	3.6	–	7.8
	Warrington C.B.C.	19.8	30.0	44.0	18.1	19.1	1.1	–	20.2	–	9.8	–	23.8
	West Lancs. W.B. (4)	2.5	3.9	4.7	5.1	5.1	–	–	5.1	1.2	–	0.4	–
	Widnes M.B.	11.3	17.0	23.0	14.0	14.0	2.0	0.5	15.5	–	1.5	–	7.5
	Wirral W.B. (2)	30.9	56.9	70.0	9.1	9.1	–	–	5.7(8)	–	51.2	–	64.3
	Totals m.g.d.	339.7	489.2	659.7	153.1	166.1	26.4(9)	24.9	164.2	3.0	328.0	1.5	497.0

NOTES: (1) *Assumes existing obligations or transfers will continue.*

(2) *Chester W.W.Co., Mid Cheshire W.B. and Wirral W.B. appear also in the Dee and Clwyd River Authority Table I.*

(3) *Liverpool C.B.C. appears also in the Dee and Clwyd and Lancashire River Authorities Tables I.*

(4) *Makerfield W.B. and West Lancs. W.B. appear also in the Lancashire River Authority Table I.*

(5) *Manchester C.B.C. appears also in the Lancashire and Cumberland River Authorities Tables I.*

(6) *Additional requirements if new town built in South Cheshire.*

(7) *North Derbyshire W.B., Oldham C.B.C. and Rochdale C.B.C. appear also in the Yorkshire Ouse and Hull River Authority Table I.*

(8) *Allowing reduction of 3.4 m.g.d. for ultimate abandonment of unsatisfactory borehole sources.*

(9) *Net gain by St. Helens of 1.0 m.g.d. from B.W.B.: 0.5 m.g.d. from N.C.B.*

East Shropshire W.B. and Leek R.D.C. omitted, as demands within the river authority area are insignificant.

TABLE II - IMPORTS

		Average daily transfer m.g.d.	
		1981	2001
Liverpool C.B.C.	transfer from Severn	44.2	44.2
" "	" " Dee	55.9	64.0
" "	" " Lancs.	2.7	1.4
Manchester C.B.C.	" " Cumberland	116.5	122.8
" "	" " Lancs.	5.1	5.1
Mid Cheshire W.B.	" " Severn	0.9	0.9
" "	" " Dee	7.3	6.8
Oldham C.B.C.	" " Yorkshire Ouse & Hull	1.6	1.6
Rochdale C.B.C.	" " " " " "	1.7	1.7
Wirral W.B.	" " Dee	24.8	24.0
North Derbyshire W.B.	" " Trent	0.8	1.8
Totals – m.g.d.		261.5	274.3

TABLE III - EXPORTS

	1981	2001
West Lancashire W.B. transfer to Lancashire – m.g.d.	1.2	0.4

TABLE IV - EFFECTIVE DEFICIENCES

	1981	2001
Effective deficiencies by deduction of imports from deficiencies in Table I – to nearest 5 m.g.d.	65	225

LANCASHIRE RIVER AUTHORITY

PUBLIC WATER SUPPLY

TABLE I

Ref. No.	Undertaking	Average daily demands m.g.			Resources m.g.d.					Apparent Overall Deficiencies(−) or Surpluses(+) on Net Resources m.g.d.			
		1967	1981	2001	1967	Authorised	(1)Bulk Supplies +	(1)Bulk Supplies −	Net Authorised	+	−	+	−
	Adlington U.D.C. (2)	0.2	0.3	0.5	–	–	0.3	–	0.3	–	–	–	0.2
	Blackrod U.D.C.	0.2	0.3	0.6	0.3	0.3	–	0.1	0.2	–	0.1	–	0.4
	Calder W.B.	9.9	13.4	19.9	8.0	10.1	1.7	–	11.8	–	1.6	–	8.1
	Chorley R.D.C.	1.5	2.0	2.7	–	–	1.7	0.2	1.5	–	0.5	–	1.2
	Craven W.B. (3)	0.8	1.1	1.3	0.7	0.8	–	–	0.8	–	0.3	–	0.5
	Furness W.B.	8.3	12.5	15.0	10.8	10.8	–	–	10.8	–	1.7	–	4.2
	Fylde W.B.	33.4	48.0	68.0	34.3	37.1	0.2	0.3	37.0	–	11.0	–	31.0
	Horwich U.D.C. (2)	0.9	1.1	1.7	0.9	0.9	–	–	0.9	–	0.2	–	0.8
	Lakes & Lune W.B.	3.5	4.2	4.8	3.7	3.7	0.8	–	4.5	0.3	–	–	0.3
	Liverpool C.B.C. (2)(4)(5)	1.5	2.6	3.9	9.5	9.5	–	4.2	5.3	2.7	–	1.4	–
	Lune Valley W.B.	9.1	10.3	12.0	12.0	12.0	0.5	–	12.5	2.2	–	0.5	–
	Makerfield W.B. (6)	8.3	12.0	18.8	1.2	1.2	10.1	2.5	8.8	–	3.2	–	10.0
	Manchester C.B.C. (7)	–	–	–	–	20.0	–	14.9	5.1	5.1	–	5.1	–
	North Calder W.B.	3.5	5.1	7.0	4.1	4.7	–	–	4.7	–	0.4	–	2.3
	Preston & District W.B.	13.9	28.9	48.4	10.2	10.7	4.3	0.1	14.9	–	14.0	–	33.5
	South Cumberland W.B. (8)	0.7	5.0	5.4	0.9	0.9	–	–	0.9	–	4.1	–	4.5
	West Lancashire W.B. (6)	6.0	10.7	13.3	3.4	3.4	2.5	–	5.9	–	4.8	–	7.4
	Withnell U.D.C. (2)	0.2	0.3	0.5	–	–	0.2	–	0.2	–	0.1	–	0.3
	Totals m.g.d.	101.9	157.8	223.8	100.0	126.1	22.3	22.3	126.1	10.3	42.0	7.0	104.7

NOTES· *(1) Assuming existing obligations or transfers will continue.*
(2) No details submitted by the undertakings. Estimates prepared from existing data.
(3) Craven W.B. appears also in the Yorkshire Ouse and Hull River Authority Table I.
(4) Demands in Chorley B.C. area only included.
(5) Liverpool C.B.C. appears also in the Dee and Clwyd and Mersey and Weaver River Authorities Tables I.
(6) Makerfield W.B. and West Lancashire W.B. appear also in the Mersey and Weaver River Authority Table I.
(7) Manchester C.B.C. appears also in the Mersey and Weaver River Authority and Cumberland River Authority Tables I.
(8) South Cumberland W.B. appears also in the Cumberland River Authority Table I,

Millom R.D.C. demands and resources within study area ignored.

TABLE II - IMPORTS

	Average daily transfers m.g.d.	
	1981	**2001**
West Lancashire W.B. transfer from Mersey and Weaver	1.2	0.4

TABLE III - EXPORTS

	1981	**2001**
Liverpool C.B.C. transfer to Mersey and Weaver	2.7	1.4
Manchester C.B.C. " " " " "	5.1	5.1
Totals – m.g.d.	7.8	6.5

TABLE IV - EFFECTIVE DEFICIENCIES

	1981	**2001**
Effective deficiencies by deduction of imports from deficiencies in Table I – to nearest 5 m.g.d.	40	105

CUMBERLAND RIVER AUTHORITY

PUBLIC WATER SUPPLY

TABLE I

Ref. No.	Undertaking	Average daily demand m.g.			Resources m.g.d.					Apparent overall deficiencies (-) or surpluses (+) on net resources – m.g.d.			
							(1)Bulk Supplies			1981		2001	
		1967	1981	2001	1967	Autho-rised	+	–	Net Authorised	+	–	+	–
	Carlisle C.B.C.	5.7	6.3	9.4	6.9	6.9	–	0.1	6.8	0.5	–	–	2.6
	Eden W.B. (2)	2.8	3.5	4.5	1.7	2.6	1.2	–	3.8	0.3	–	–	0.7
	Keswick U.D.C.	0.4	0.4	0.5	0.4	0.6	–	–	0.6	0.2	–	0.1	–
	Manchester C.B.C. (3)	–	–	–	102.0	124.0	–	1.2	122.8	122.8	–	122.8	–
	S. Cumberland W.B.	9.6	31.7	49.0	9.7	15.7	0.4(4)	–	16.1	–	15.6	–	32.9
	W. Cumberland W.B. (5)	7.8	22.2	29.0	14.6	16.6	0.1	–	16.7	–	5.5	–	12.3
	Totals m.g.d.	26.3	64.1	92.4	135.3	166.4	1.7	1.3	166.8	123.8	21.1	122.9	48.5

NOTES: *Lakes and Lune W.B. within Cumberland R.A. area, resources and demands less than 0.1 m.g.d., not included.*

(1) Assuming existing obligations or transfers will continue.
(2) Eden W.B. appears also in the Northumbrian River Authority Table I.
(3) Manchester C.B.C. appears also in the Mersey and Weaver and Lancashire River Authority Tables I.
(4) Net gain of 0.4 m.g.d. from U.K.A.E.A.
(5) South Cumberland W.B. appears also in the Lancashire River Authority Table I.

TABLE II - IMPORTS - NIL

TABLE III - EXPORTS

	1981	2001
Manchester C.B.C. transfer to Mersey and Weaver – m.g.d.	116.5	122.8

TABLE IV - EFFECTIVE DEFICIENCIES

	1981	2001
Effective deficiencies from Table I – to nearest 5 m.g.d.	20	50

APPENDIX II

APPENDIX II: INDUSTRIAL RIVERS

1. On inland reaches of rivers where major industrial use and re-use cycles occur it is necessary to assess for any point on the river:

   (a) the present resources of the river in terms of its capacity to sustain further losses from dry weather flows, or to absorb further heat or contaminant loads;

   (b) the effects of any likely future abstractions and discharges on those resources (e.g. assumed growth in demand for public water supplies implies increased discharges of sewage effluents which may permit further net abstractions).

Analyses of these variables is most conveniently effected and displayed in the form of a residual flow diagram. This indicates for given flow conditions at a given date the expected pattern of abstractions and returns and hence the residual resources.

2. A river, or reach of river, is represented by a central vertical axis to the left of which is plotted the estimated natural dry weather flow of the river to any desired degree of design severity. Artificial interferences with natural flow are plotted cumulatively in the downstream sequence in which they occur; positive contributions - compensation water or effluent discharges - to the right and abstractions to the left of the axis so that the horizontal distance between the natural and artificial flow lines gives the residual flow in the river at any point along its length. Specimen diagrams compiled in this way are included at the end of this Appendix

3. The artificial flow line will cross the vertical axis if cumulative abstractions exceed cumulative artificial contributions, indicating that the abstraction is being made at the expense of the natural dry weather flow of the river. The extent to which any such abstraction may be at risk in dry weather can be illustrated by considering a family of curves representing the natural dry weather flow in the river for different probabilities of occurrence.

4. The degree of risk which will be acceptable to any particular abstractor must involve the economics of loss of output, storage of product, storage of water on site, etc. Evaluation of these considerations lies beyond the scope of this study. In the examples which are attached at the end of this Appendix curves have been plotted either for one set of flow conditions taken from historic data for an exceptionally dry period, or dry weather flows calculated for one or two statistical probabilities - the driest week in any one year or the driest week in any ten years. We do not purport to draw any conclusions from any of these design conditions.

5. Had we been able to establish acceptable degrees of risk, and hence the dry weather flow conditions appropriate to our considerations the next step in our assessment of existing resources would have been the determination at any point or points in the river system of the minimum residual flow necessary to safeguard all riparian requirements. As in the previous considerations, determinations of such minimum flows is a complex matter which will demand continuing study by the river authorities. No determinations have yet been made for any of the northern rivers with which we are concerned.

6. Thus the residual flow diagrams of existing conditions fall short of a general statement of the net resources at present available at any point in the system. They do however provide guidance on the location of river reaches where residual resources are relatively ample or scarce.

7. Most of the industrial rivers with which we are concerned receive considerable contributions to artificial flow from effluents discharged from sewage treatment works. In our survey of public water supply demand we estimated that over the next 30 years or so consumption would rise at the rate of about 3% per annum. Sewage effluents must show a similar increase and the residual flow diagrams can therefore be extrapolated to show the increased residual flows which will be available by the end of the century, if abstractions remained unchanged.

8. Similarly if industrial abstractions and returns are assumed to grow, at say 4% per annum, the overall effect of increased abstractions and increased sewage effluents on the final residual flows can be displayed at any target date. In the examples attached those extrapolations have been made for conditions at 2001.

9. If the extrapolation shows that at no point in the river is the final residual flow likely to be less than under present conditions, then on the assumption that existing conditions are tolerable, future abstractions will be covered by increased sewage effluent discharges and no provision need be made to supplement river flows. There may, of course, be cases where dry weather flows will require augmentation for amenity purposes but we have not envisaged the provision of new resources for this purpose in any of the cases considered here.

10. It must be emphasised that these extrapolations assume that the additional sewage effluents will be discharged as a proportionate increase in existing effluents at the same points in the river system and that future industrial demand may be represented by an increase in existing uses. This is unlikely to be the case. Some future sewage effluents may be treated at existing works, extended to cope with the additional load, but others may be treated at new sewage treatment works designed to cover a number of existing authorities with the final effluent discharged at a new location. Similarly industrial growth at an existing abstraction point may be restricted by the limitations of the site and a new demand may arise elsewhere on the river.

11. These variations in effluent discharges and abstractions will in due course require the consent of the river authorities under the Rivers (Prevention of Pollution) Acts or the Water Resources Act but it is obviously impossible at this time to attempt to predict the effects of all possible variations. For the present exercise we have assumed that provided the estimated increase in effluents exceeds the estimated increase in net abstractions, a balance can be achieved by detailed planning of future points of abstraction and discharge. On this basis the industrial direct abstraction demands have been analysed for the industrial rivers of the north leading to the conclusions in Chapter 3.

TABLE II/1

INDUSTRIAL RIVERS

EXPECTED VARIATIONS IN ARTIFICIAL FLOWS

River	Present minimum flow	1981			2001		
		Estimated increase in sewage effluents	Possible increase in net industrial demand	Net residual flow	Estimated increase in sewage effluents	Possible increase in net industrial demand	Net residual flow
	m.g.d.	m.g.d.	m.g.d.	m.g.d.	m.g.d.	m.g.d.	m.g.d.
Aire	34	12	6	40	25	9	50
Calder	52	12	5	57	28	19	61
Don	48	18	18	48	43	44	47
Irwell[1, 2]	61	16	–	77	40	-	101
Mersey[1, 2]	60	14	–	74	36	–	96
Bollin[1, 2]	12	4	–	16	10	–	22
Weaver[1]	34	4	3	35	10	4	40
Douglas	20	6	2	24	15	4	31
Ribble	80	14	3	91	33	7	106

12. The analyses have been confined to consideration of quantity only and it has not been possible to extend them to cover temperature and water quality. The same basic approach can be applied to any parameter, and will undoubtedly be a necessity for efficient river management in the future. At present comprehensive processed data does not exist; its acquisition and the development of techniques of analysis will involve years of work.

13. Water quality is obviously an important factor which the analyses have not taken into account. In general it is desirable that improvement in effluent standards should at least suffice to maintain present standards of quality in rivers; in certain cases it will be desirable to set improved quality 'targets' for specific river reaches. Within this framework, opportunities should be sought for locating new abstractions where suitable qualities as well as quantities are available before having recourse to river regulation or other special measures to improve the quality of water available for abstraction.

1. *Selected rivers from a complete analysis of the whole of the River Authority area.*
2. *On these rivers detailed analysis indicated no overall growth in direct abstraction. Over recent years the trend has been towards transfer of demand for high quality water to the public supply. This trend is expected to continue and is reflected in the estimates of public water supply metered consumption in the Mersey and Weaver area in Table A of Chapter 2.*

14. Samples of the residual flow diagrams used in the analyses are attached for the following rivers:-

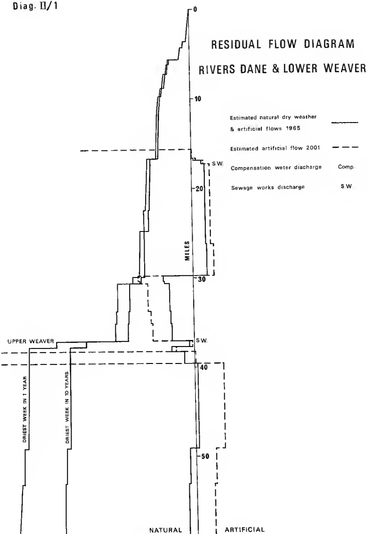
1. Dane and Lower Weaver
2. Irwell
3. Aire
4. Calder
5. Don

15. The Dane and Lower Weaver is a river system on which the growth of abstractions may exceed the estimated increase in effluent discharges and augmentation of river flows may be necessary. In this case schemes are included in the isolated sources schedule which could meet thia need. The River Irwell is an example of a river where existing effluent discharges far exceed net abstractions and where growth at the expected rates will increase dry weather flow.

16. The diagrams for the Aire, Calder and Don are composite diagrams for the whole of these main rivers and summarise the overall position in the river authority area. In all the lower reaches increased effluents exceed any probable growth in abstraction. In the upper reaches and on some of the tributaries, where this is not the case, existing abstractions are for old established industries where little growth is expected.

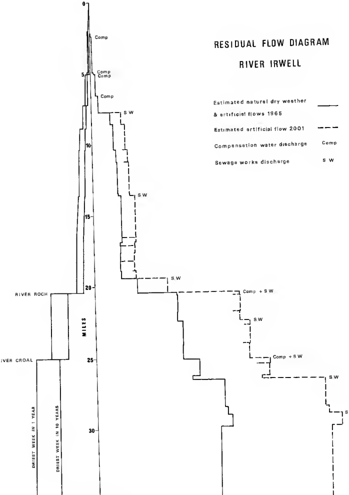
17. For the industrial rivers which have been analysed total additional contributions to flow and estimated increases in net abstraction are summarised in Table II/1 opposite.

Diag. II/1



RESIDUAL FLOW DIAGRAM

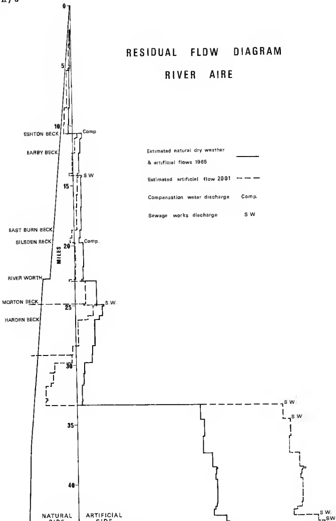
RIVERS DANE & LOWER WEAVER



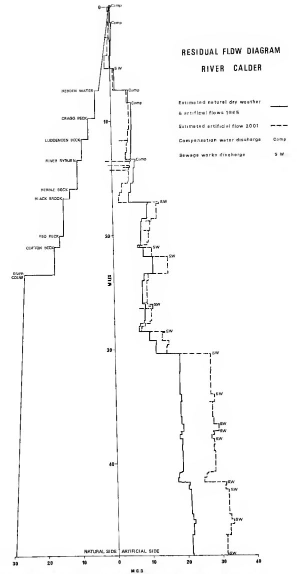
RESIDUAL FLOW DIAGRAM

RIVER IRWELL

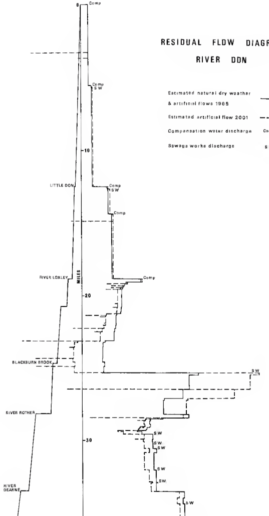
Diag. II/3


RESIDUAL FLOW DIAGRAM
RIVER AIRE
Estimated natural dry weather & artificial flows 1965
Estimated artificial flow 2001
Compensation water discharge Comp.
Sewage works discharge S W
ESHTON BECK
EARBY BECK
EAST BURN BECK
SILSDEN BECK
RIVER WORTH
MORTON BECK
HARDEN BECK
Comp
S W
Comp.
S W.
S W.
S W
S W.
S W.
MILES
0
5
10
15
20
25
30
35
40
NATURAL SIDE
ARTIFICIAL SIDE
10
5
0
5
10
15
20
25
30
35
40
M.G.D.

RESIDUAL FLOW DIAGRAM
RIVER CALDER



RESIDUAL FLOW DIAGRAM
RIVER DON

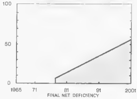


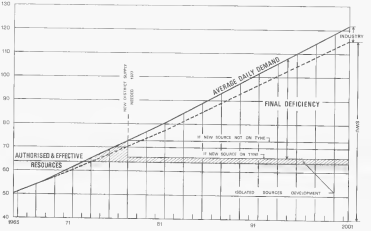
APPENDIX III

Diagrams 1-13 Demands/Resources diagrams for demand districts

Diagram 14 Growth of Demand

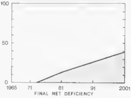
NEWCASTLE DISTRICT

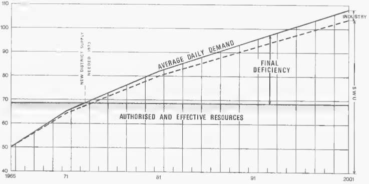




FOR KEY SEE Diag III/13

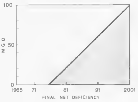
SUNDERLAND DISTRICT

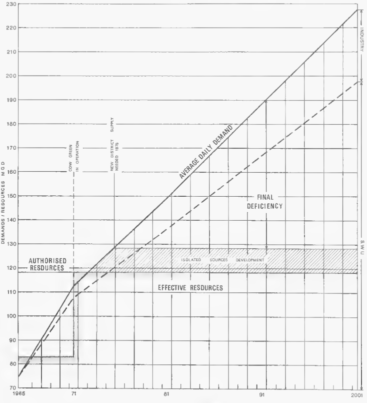




FOR KEY SEE Diag III/13

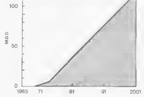
TEESSIDE DISTRICT

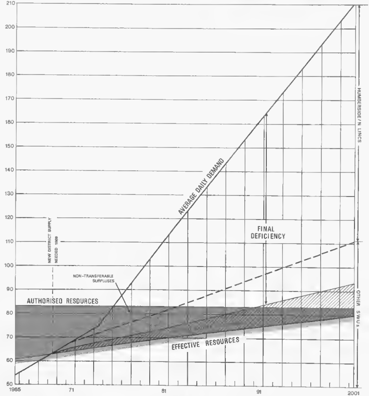




FOR KEY SEE Diag III/13

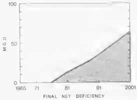
HULL AND HUMBERSIDE DISTRICT

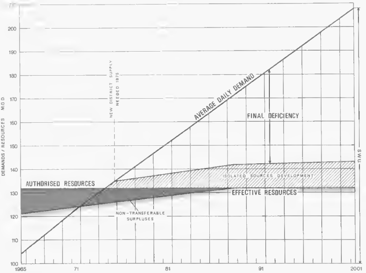




FOR KEY SEE Diag III/13

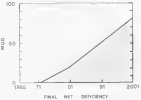
WEST RIDING
NORTH DISTRICT

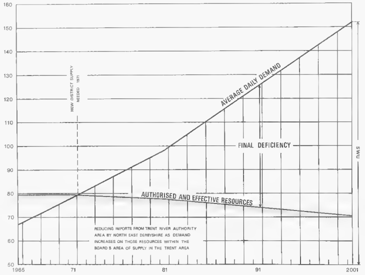




FOR KEY SEE Diag III / 13

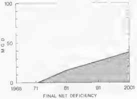
WEST RIDING SOUTH DISTRICT

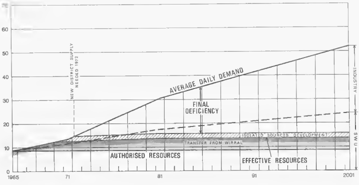




FOR KEY SEE Diag III/13

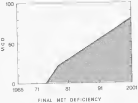
FLINT / DENBIGH DISTRICT

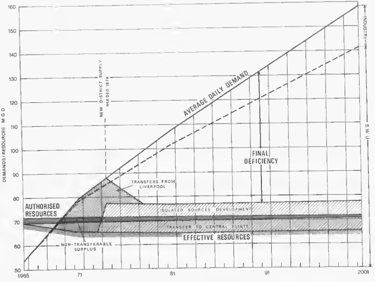




FOR KEY SEE Diag III / 13

CHESTER DISTRICT





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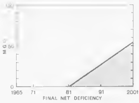
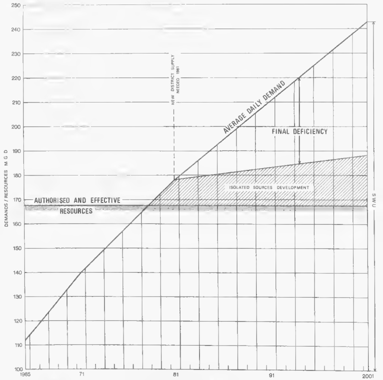
LIVERPOOL DISTRICT





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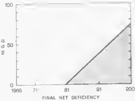
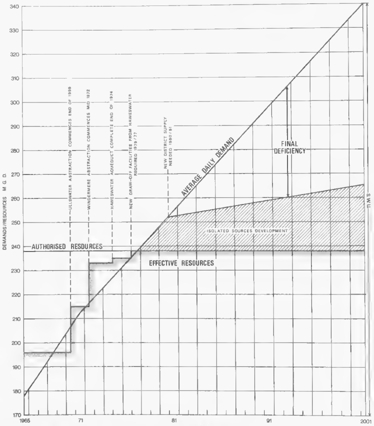
MANCHESTER DISTRICT

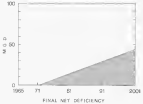


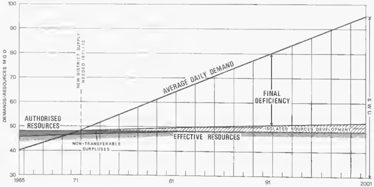
FINAL NET DEFICIENCY



FOR KEY SEE Diag III/13

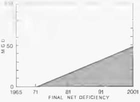
PRESTON DISTRICT

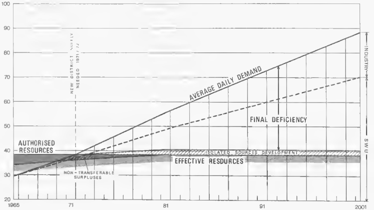




FOR KEY SEE Diag. III/13

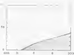
FYLDE DISTRICT



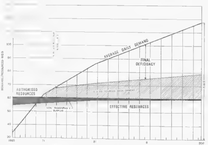


FDR KEY SEE Diag. III /13

CUMBERLAND DISTRICT



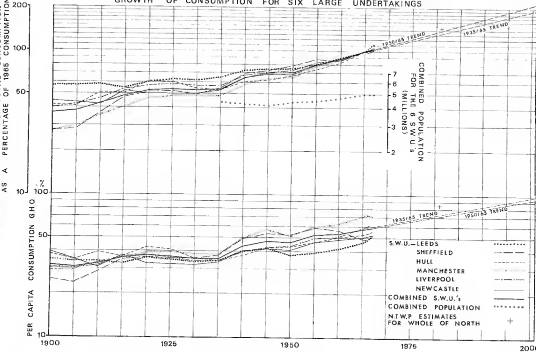
FINAL NET DEFICIENCY



Total average daily demand including the net industrial deficiencies from Table C Chapter XI	—
Average daily demand for S W Us within the demand district abstracted from Table I Appendix I	- - -
Effective resources: resources which after allowing for transfers and non-transferable surpluses are available to offset the total demands	—
Surpluses of S W U's which cannot be transferred to meet deficiencies elsewhere in the district	■
Temporary transfers of surpluses from other districts	▒
Suggested permanent transfers of supplies	□
Isolated sources development	▨

PUBLIC WATER SUPPLIES IN THE NORTH

GROWTH OF CONSUMPTION FOR SIX LARGE UNDERTAKINGS



Diag III/14

APPENDIX IV

APPENDIX IV: WATER QUALITY

1. We indicated in Chapters 2 and 6 that, in the main, water supplies in the north have been drawn traditionally from direct supply reservoirs. It is only in recent years that a significant part of the supply has been derived from river abstractions. Development programmes in which the bulk of future supplies would come from regulated rivers would thus present treatment problems on a scale not previously encountered.

2. The investigation of these problems was referred to a Sub-Committee of chemists drawn from water undertakings and river authorities. The following served on the Committee and we are indebted to them for their services in producing the report upon which this Appendix is based.

J. W. Atkinson B.Sc., PAIWE, FCS.	Manchester Corporation W.Wks.
F. Bell B.Sc., ARIC.	Newcastle and Gateshead W.Co.
W. K. Ellison B.Sc., FRIC., MIWPC, FCS.	Lancashire River Authority.
M. A. Hilson ARIC, PAIWE.	Fylde Water Board.
E. Howarth LRIC.	Bradford Corporation W.Wks.
M. Lovett O.B.E., B.Sc., FRIC, FISP.	Yorkshire Ouse and Hull R.A.
A. T. Palin B.Sc., Ph.D., FRIC.	Newcastle and Gateshead W.Co.

3. The general objectives of the Sub-Committee were to establish the differentials in treatment costs implied by a change from the present direct supply sources to supplies from regulated rivers or barrages; and in addition to identify industries with special requirements for which a change in supply might entail the cost of additional treatment above that required for potable supplies.

4. The investigations involved:

   (a) an assessment of probable raw water qualities from regulated rivers and from barrages;

   (b) an assessment of treated water quality requirements for domestic and general trade and for special industrial uses;

   (c) an assessment of the treatment necessary and an estimate of treatment costs.

Estuary schemes - raw water quality

5. Conclusions as to the quality of raw water which will be made available from any developments in the estuaries must obviously await the completion of full feasibility studies. In the meantime the Sub-Committee studied the limited data which were available with a view to providing preliminary estimates of treatment costs for use in economic comparisons.

6. In the case of Morecambe Bay, analyses of the composition of the rivers flowing into the Bay were provided by the Lancashire River Authority on the basis of samples taken from April to December 1967. Estimates of the chloride level in a direct impoundment given in the barrage desk study were supplemented by advice from Professor L. Huisman of Delft Technological University, Holland.

7. The Sub-Committee considered that the bacteriological quality of the raw water was likely to fall into Class II of the World Health Organisation standards for raw water and that conventional treatment methods of coagulation, sedimentation, filtration and disinfection as proposed by the consulting engineers in the desk study report would be applicable. Average total hardness was thought unlikely to exceed 70 mg/l and the final chloride concentrations were considered to be of significance only in relation to dezincification of duplex brass fittings. Taste problems may well arise from the growth of algae but even more intractable waters can now be handled by modern techniques in the treatment plant proposed.

8. In the case of Dee and Solway no additional data was available and the assessments made by consulting engineers in the desk study reports were accepted.

Regulated river supplies - raw water quality

9. The rivers considered as possible sources of supply and the notional abstraction points are given in Schedules II of Appendix IX. From the outset it had to be accepted that time did not permit the setting up of a sampling programme and that assessments would have to be based upon the existing records of river authorities and water undertakings for the sampling point nearest to the point of abstraction. (The need for a comprehensive programme of sampling on those rivers likely to be future sources of supply was emphasised so that more complete data will be available when treatment plants are being designed).

10. Existing data consisted of analyses of monthly samples from river authority records supplemented in the cases of Lancashire and Northumberland by other analyses provided by the statutory water undertakings and industrialists. Scrutiny of the data gave the range and mean value in the natural river flow of the key parameters determining the costs of treatment of raw waters to potable standards. (Hardness, alkalinity, colour, turbidity, chloride content and pH value). In some cases data on colour and turbidity was not available and inferences had to be drawn from records of suspended solids and B.O.D.

11. In regulation schemes abstractions must be made from the natural river flows for about half of the average year. In some cases this water may be pumped into bulk storage before being passed into supply, but in general it will be pumped, possibly after short retention in tactical storage, directly to treatment and supply. Consideration of the effects of regulation on the quality of the water at the abstraction point requires detailed knowledge not only of river water quality and variation with flow, but also of the quality of the water impounded and the proportion of releases from the reservoir to natural river flow. Such data will not be available until specific sites are selected and detailed investigations have been completed. At present assessments of average treatment requirements can only be based upon the range of quality of the natural river assuming that treatment plant must be provided to cope with the worst conditions encountered and average maintenance costs assessed on the mean quality within the limits of the data available.

12. On these assumptions the Sub-Committee concluded that all the proposed river regulated sources could be treated by conventional coagulation, sedimentation, filtration and disinfection to provide water of a quality acceptable for general domestic and the bulk of industrial purposes. In the special cases of the three lakeland rivers, Leven, Duddon and Calder/Bleng, coagulation, filtration and disinfection would probably be adequate.

Treated water requirements

13. The Sub-Committee's standards for general domestic use followed broadly the World Health Organisation International Standards for drinking water supplies with the exceptions that a total hardness limit of 150 mg/l was adopted and a lower level of chlorides was suggested in an endeavour to alleviate the dezincification problem. The latter suggestion was qualified however by a recommendation for detailed investigation into probable chloride levels from barrage supplies coupled with fundamental research into the factors causing dezincification, and a conclusion that if dezincification remained the only objection to an otherwise acceptable and economic supply then the higher W.H.O. limit of 250 mg/l for chlorides could be tolerated and the use of duplex brass fittings precluded.

14. The review of special industrial requirements was based upon examination of literature, data resulting from enquiries by the Manchester Corporation Waterworks and enquiries to individual industries and Research Associations. Consideration of this information led to the conclusion that the textile and associated industries, traditionally established in the soft water areas (Demand Districts Preston, Liverpool, Manchester and West Riding North) were the only major industrial group with general quality requirements more stringent than the proposed standards for potable supplies. For these industries the critical quality parameter is total hardness and a level of 70 mg/l is the maximum permissible without additional treatment at the factory.

15. Many of the rivers considered as sources of supply have a mean hardness in excess of 70 mg/l and supplies from these sources should carry a weighting if considered for use by industry in any of the districts listed above. The possibilities of separate industrial supplies or of additional site treatment of the industrial sector were considered but it was suggested that for these areas the practical - and probably the economic solution - was to allow in the estimated costs of treatment for softening the whole of the supply down to 70 mg/l.

16. It was accepted that even this standard might involve a few consumers with particularly stringent requirements in trouble or expense but these will only use a very small proportion of the total supply and the additional costs would be insignificant in the overall comparisons. Abrupt variations in quality also raise problems and in areas accustomed to very soft water the introduction of new supplies of 70 mg/l hardness calls for controlled blending leading to a gradual and predictable increase in total hardness.

Treatment Costs

17. The Sub-Committee considered the data available from the Water Research Association survey into conventional water supply costs (W.R.A. T.P. 60 1967), recently published cost and estimating data and maintenance and operating

costs provided by members for their own and other water undertakings. Independent assessments were also made of the cost of chemicals required for the treatments envisaged based upon current prices. The various approaches produced costs in reasonably close agreement and the unit costs given in Table IV/1 below were adopted.

TABLE IV/1

Treatment Costs pence per 1000 gallons			
Treatment	Capital Cost	Maintenance and Operation	Total
Single stage treatment (no sedimentation)	1.5	1.0	2.5
Two stage treatment	3.0	2.0	5.0
Lime softening	-	0.005H	0.005H
Soda softening	-	0.021H	0.021H
Stabilisation after Lime or lime-soda softening	-	0.15	0.15
Ion Exchange softening	-	-	0.03H

H refers to the amount of hardness to be removed in mg/l of $CaCO_3$.

18. It was assumed that basic two stage treatment plant would be similar in all cases and that lime soda softening if required would be carried out in the sedimentation tanks (using chlorinated copperas as a coagulant) with no addition to capital costs other than the storage facilities required for additional chemicals. A representative capital cost of £55,000 per m.g.d. was assumed, equivalent to a unit cost of approx. 3.0d. per 1000 gals. Ion exchange softening was proposed only for those waters not amenable to lime soda softening e.g. the River Lune, the hardness of which would have to be reduced from 90 mg/l to 70 mg/l for special industrial requirements, a range in which lime soda softening may not be effective.[1] In this case the process would have to be superimposed on the basic treatment and the unit cost quoted includes the capital cost of the additional plant. Estimates of chemical requirements included an allowance for 5 mg/l of activated carbon for taste removal because river derived waters will almost certainly pose taste problems at times.

19. Table IV/2 lists the proposed sources and possible destinations together with the maximum and mean total hardness obtained from the analyses described in paras. 9 and 10. On the assumptions that all supplies will be softened if necessary to provide a water for general purposes not exceeding 150 mg/l hardness and that the water supplied to the special industrial areas will be softened to 70 mg/l hardness, the unit costs in Table IV/1 have been applied to give a specific treatment cost for each source to each destination within its command area as tabulated in Table IV/2.

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[1] *Experiments carried out subsequently have indicated that lime pellet softening may be practicable on water from the River Lune.*

20. The precise figures given for treatment costs may seem to imply a greater knowledge of raw water quality and treatment requirements than is possible from the limited data available. They are, however, no more than the application of the estimated basic unit costs to the average qualities of the selected sources as assessed on present knowledge. More comprehensive and more detailed investigation should obviously precede the design of individual schemes and specific projects may show quite wide variations from the average. The Sub-Committee was confident, however, that the costs quoted represented nearly enough the real differences in average treatment costs for the types of source and the demand districts concerned.

TABLE IV/2

Estimated Water Treatment Costs

Source River	Hardness Max (ppm $CaCO_3$)	Hardness Mean (ppm $CaCO_3$)	Treatment cost pence/1,000 galls at destination									
			Newcastle/Sunderland	Teesside	Hull/Humberside	West Riding North	West Riding South	Flint/Denbigh	Chester	Liverpool/Manchester	Preston	Cumberland
Coquet	175	130	5.0	–	–	–	–	–	–	–	–	–
Tyne	194	140	5.0	5.0	5.0	5.5	5.0	–	–	–	–	–
Wear	336	220	5.5	5.5	5.5	6.0	5.5	–	–	–	–	–
Tees	300	185	–	5.3	–	–	–	–	–	–	–	–
Yorks. Derwent	332	230	–	–	5.6	6.0	5.6	–	–	–	–	–
Wharfe	252	175	–	–	5.3	5.7	5.3	–	–	–	–	–
Ouse (Nun Monkton)	325	200	–	–	5.4	5.8	5.4	–	–	–	–	–
Ouse (Selby)	295	200	–	–	5.4	5.8	5.4	–	–	–	–	–
Clwyd	–	<150	–	–	–	–	–	5.0	–	–	–	–
Dee	143	95	–	–	–	–	–	5.0	5.0	5.3	–	–
Ribble	248	150	–	–	–	5.6	5.0	–	–	5.6	5.6	–
Lune	126	87	–	–	5.0	5.5	5.0	–	–	5.5	5.5	–
Wyre	50	42	–	–	–	–	–	–	–	–	5.0	–
Kent	108	79	–	–	5.0	5.3	5.0	–	–	5.3	5.3	–
Leven	30	25	–	–	–	–	–	–	–	2.5	2.5	–
Duddon	–	< 30	–	–	–	–	–	–	–	2.5	2.5	2.5
Calder/Bleng/Irt	–	< 70	–	–	–	–	–	–	–	–	–	2.5
Cumberland Derwent	–	< 70	–	–	–	–	–	–	–	–	–	5.0
Eden	–	80	5.0	5.0	–	–	–	–	–	–	–	5.0
Morecambe Bay Barrage	–	65	5.0	5.0	5.0	5.0	5.0	–	–	5.0	5.0	5.0
Solway Barrage	–	80	5.0	5.0	5.0	5.3	5.0	–	–	5.3	5.3	5.0

APPENDIX V

Pnnted ımage dıgıtised by the Unıversity of Southampton Lıbrary Dıgıtisatıon Unit

APPENDIX V: GEOLOGY

1. Within the region are found rocks which range in age from the Ordovician and Silurian of the Lake District to the Cretaceous Chalk of East Yorkshire. Large areas of these are masked by superficial deposits consisting of glacial boulder clay, sand and gravel and post-glacial gravels, peats and alluvium. The Pennine Chain of Carboniferous strata, which runs southwards from the Scottish border to the southern margin of the region, separates the Lake District and post-Carboniferous deposits on the west from those on the east. On the flanks of the Pennines are the coalfields of Northumberland and Durham, Lancashire and Yorkshire; coal and iron fields fringe the Lake District. Permian and Triassic strata occur on the east, north and west sides of the latter district, in South Lancashire and Cheshire and also in a broad band from the north-east coast near Hartlepool southwards to Doncaster. Younger strata dip eastwards off this eastern outcrop.

2. Within the area of the study preliminary consideration has been given to almost 100 possible dam sites, the majority of them on the Carboniferous strata of the Pennines. A desk study of existing maps and records, supplemented by field inspection of a limited number of sites, enabled a choice to be made of likely locations for reservoirs. All of the sites suggested, listed in the schedules of resources in Appendix IX, would require detailed investigation.

3. The major and minor aquifers within the report area occur in the relative stratigraphical positions listed in Table V/1. This is not a complete sequence of strata but is intended only to provide an indication of the positions of aquifers relative to other formations, the intervening relatively impermeable beds not being listed. The general distribution of these aquifers in the north is shown in Figure V/1.

TABLE V/1

	Formation	Type of Aquifer
Pleistocene and Recent (superficial deposits)		alluvium and river gravels glacial sands and gravels
Cretaceous	Chalk	fine-grained soft limestone
Jurassic	Corallian	calcareous sandstones and oolitic limestones
Trias	Keuper Sandstone Bunter Sandstone	red, yellow and white sandstones
Permian	Magnesian Limestone St. Bees Sandstone Basal Sand Penrith Sandstone Collyhurst Sandstone	yellow limestones, sandstone poorly-cemented sand
Carboniferous	Coal Measures Millstone Grit	sandstones and shales
	Carboniferous Limestone	massive limestones, thin limestones, sandstones and shales

4. Ground water has been developed, as immediate local needs have arisen, by sinking individual wells or boreholes into suitable aquifers. In this way almost full use of the long-term natural inflow to parts of certain aquifers such as the Triassic sandstones of south Lancashire has already been reached. Opportunities now arise of developing the storage within ground-water units more efficiently, by intermittent abstraction combined with surface run-off. In addition in certain areas it may be possible to replenish aquifer storage by systems of induced or artificial recharge, but more needs to be known of the techniques involved.

5. If changes in abstraction patterns are proposed so that, for instance, rates of abstraction are increased over limited periods then care must be taken to ensure that the likely resultant effects, particularly on stream discharge, are predictable and acceptable. In some localities uncontrolled abstraction over long periods in the past has led to the flow of saline or brackish water into aquifers bordering the coast, and in others to the flow of highly mineralised ground waters or brines, either from deeper levels of the aquifer or from neighbouring masses of strata. If further gains in overall reliable yields are to be achieved by combined use of surface and ground-water resources then detailed investigation of the aquifer properties is required over a period of several years.

6. When considering the possible development of any ground-water resource it must be borne in mind that the accuracy of assessment of the resource depends, in most cases, on a knowledge of parameters which themselves cannot be measured very exactly. Initial calculations of ground-water resources may be made from meteorological data, supplemented where possible by an assessment of the ground-water component of stream discharge from the relevant catchment. At present it is possible in only a few cases to determine changes in storage within an aquifer from a consideration of long-term abstraction and water-level fluctuation data.

7. Assessments of ground-water resources have been made in some detail for particular areas where it appeared that these resources might need to be developed within the next decade. A number of isolated sources have been examined by statutory water undertakings, and broader investigations of parts of aquifers have been undertaken in the Fylde area and in the Tees Valley.

8. The potential yield of individual wells within the major and minor aquifers described in paragraph 3 above varies within wide limits. Areas in which ground-water could be developed in significant quantities are described below for each river authority area and are indicated on the map (Figure V/1). In addition those ground-water resources which may be developed within an overall regional plan are indicated on Map 5C.

Northumbrian River Authority

9. The principal aquifers are the Permian Magnesian Limestone and the Triassic sandstones. Ground-water in the Limestone has been abstracted for some years in the Hartlepools and Darlington areas. Recent investigations carried out between these two areas since November, 1967, have shown that up to 6 m.g.d. are available perennially from the Limestone within the catchment of the Skerne and Billingham Beck. A further 4 m.g.d. are probably available from this aquifer

within the river authority area. There are at least 5 m.g.d. available from the Triassic sandstones, but the distribution of mineralised ground-water within this aquifer is not clearly known. These developments are unlikely to reduce minimum stream flow.

10. Isolated sources can be developed in the Carboniferous strata but the yields from individual wells will not exceed a few thousands of gallons per hour. During the early 1960's more than 90 m.g.d. were pumped to waste from mine drainage, the quantities thus discharged to streams and river systems have been reduced over recent years although it must be presumed that most of this water now reaches the stream by natural discharge. Much of this ground-water is highly mineralised and is not suitable for domestic and most industrial supplies without expensive treatment. In certain areas, however, where mining operations have been discontinued there are limited resources which might be developed but detailed investigations of quantity, quality and costs need to be carried out; on the other hand the abandonment of mines in some areas might appreciably reduce present dry weather flows - for instance, in the River Wear.

11. Limited supplies may be provided by development of ground water within superficial deposits in the valleys of the Tyne and Tees basins.

Yorkshire Ouse and Hull River Authority

12. There are substantial quantities of ground-water available within the authority's area but much is contained within secondary aquifers of the Jurassic and Carboniferous strata and can be developed only by a large number of bores with individual yields of the order of 0.25 m.g.d.

13. The Chalk and Triassic sandstones represent the most productive aquifers. It may be possible to develop ground-water storage in the Chalk of East Yorkshire for regulation of the River Hull. A yield of about 10 m.g.d. might be available but detailed local investigations are required to determine the feasibility and costs of such a scheme. The Triassic sandstones in the Vale of York could be developed in a similar way but boreholes would need to be dispersed over an extensive area along the north to south outcrop of the aquifer. Care would need to be exercised with regard to rates of abstraction to ensure that mineralised ground-water could not contaminate the aquifer.

14. Ground-water resources in the Jurassic strata and superficial deposits in the Vale of Pickering could be developed to meet the small local demands but might also be of limited use in maintaining stream flows for the benefit of users further afield. For this purpose they would need to be studied in detail.

Dee and Clwyd River Authority

15. Additional ground-water could be abstracted, in comparatively small quantities, from the Triassic sandstones in the Vale of Clwyd and on the western margin of the Cheshire Basin. A study of the former has led to proposals to investigate, by drilling and testing wells, the possibility of developing underground storage to provide a yield of 3 or 4 m.g.d. as a first stage in the regulation of the River Clwyd.

16. Increased abstraction from the sandstones in West Cheshire by the Dee and Clwyd and the Mersey and Weaver river authorities may lead to problems of mutual interference with resources between the two areas. Such problems will arise as development of the aquifer proceeds, and possible interference effects will have to be taken into account when future applications for licences are made. There is unlikely to be more than 4 m.g.d. available from this source. Similar quantities may be available from the Carboniferous strata, but in smaller quantities at individual sites to satisfy isolated local demands.

Mersey and Weaver River Authority

17. Most of the available ground-water resources have either been developed or determined by exploratory drilling and testing. Some isolated sites still remain to be developed, but in all cases cognisance must be taken of existing abstractions and of local hydrogeological problems such as saline intrusion or the presence of mineralised ground-water or brines.

18. Further attempts to increase reliable yields from combined use of surface and ground-water resources will require detailed investigation of these aquifers over a period of time. Administrative difficulties will arise because of the complicated pattern of use made of this aquifer by a number of statutory water undertakings and industrial concerns. Ground-water levels are known to be falling locally indicating that more ground-water is being abstracted from the aquifer than is replaced on average by natural recharge. Any scheme to increase the reliable yield, through combined use, would need to be designed to arrest the continuing fall in ground-water levels, and so to protect the aquifer from progressive invasion by poor quality ground water. The river authority is actively investigating the ground-water conditions in its area and intends to record its initial findings in the Periodical Survey in the near future. In the meantime, extreme caution is needed when making estimates of future yields of the sandstone aquifer in this difficult area.

Lancashire River Authority

19. Isolated local demands can be satisfied in parts of the authority's area from ground-water resources within the Carboniferous, Permo-Triassic and superficial deposits.

20. An analysis of available data indicates that the long term natural recharge of the Triassic sandstones between the Ribble and Lune estuaries is of the order of 16 m.g.d. most of which is already committed by existing licences for continuous abstractions. Higher yields can be obtained if increased abstraction over shorter periods is suitably combined with abstraction from surface sources, but the effects of abstraction at high rates, particularly on stream flow, need to be determined.

21. An intensive investigation is being carried out in the Fylde area to determine methods of development of part of this resource combined with river abstractions. We have estimated a net gain of 15 m.g.d. by combined use of the ground-water resources in the area between Garstang and Broughton together with existing upland catchments and storage and suitable river abstractions. This quantity is incorporated in Schedule II for the rivers Lune, Wyre and Ribble.

Ground-water resources in the remainder of this aquifer could perhaps be developed in a similar way, possibly using the Lancaster Canal as a transmission link with other surface sources.

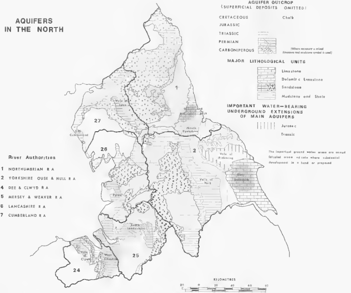
Cumberland River Authority

22. A desk study of the hydrogeology of the Triassic sandstones of West Cumberland suggests that approximately 6 m.g.d. might be available from 8 or more boreholes, without creating any serious problems with regard to the metalliferous mining being carried on in part of the area. Further investigations are needed.

23. Preliminary assessments of ground-water resources in the Triassic strata in the Vale of Eden and in the Carlisle Basin indicate that 25 m.g.d. at least could be drawn from this aquifer, although the yields from individual wells may be less than 0.5 m.g.d. If this is not to be partly at the expense of flow in the River Eden, however, the scheme would have to be developed as an underground storage scheme for regulation of the river, in which case an even higher yield is probably attainable. There is only a limited local demand for these potential resources at present, and because of location, entailing high transmission costs to other areas, they do not have any significance in the regional conservation programmes.

Diag X/1

AQUIFERS IN THE NORTH



APPENDIX VI

APPENDIX VI: VALUATION OF RECREATIONAL BENEFITS

1. In presenting regional conservation programmes we have been conscious of the lack of any ready means of evaluating the losses and gains to amenities, including recreational potential, which the schemes might imply. In this context it is in no way helpful to speak of any amenity as priceless because when one scheme is preferred to another, the process of choice involves some pricing even if this is unconscious. Equally any loss to amenity cannot be disregarded simply because it cannot be quantified in a calculation where the other factors can be priced.

2. The difficulties involved have received some attention from investigators in this field, particularly in America. One primitive method that has been used is to arrive at some indication of the recreational potential of a particular site by measuring the gross volume of business generated. But apart from the obvious practical difficulties of arriving at such an estimate, there are so many conceptual problems that the method hardly merits serious consideration. These include the problem of how to distinguish expenditure generated by the site and what is merely bought there that would otherwise have been bought at home, and identifying what is bought at home although directly generated by the site. Another serious shortcoming is the absence of comparability between the gross expenditure data and estimates of the gross outputs of other activities made possible by the same resources. Even if the gross expenditure by visitors were equal to the gross value of any water that might be supplied it would not follow that each was of equal economic significance. 'Turnover' in this sense is no indication of the respective real contributions to the nation's resources.

3. One refinement of this approach which would meet some of the basic objections would be to estimate the value added to the national income or product at the site. Such an approach would deduct the outgoings of those providing services at the site from the gross expenditure of visitors to the site, so that the recreational 'value' added in this way could be compared with the value added by alternative uses of the site. But while value-added estimates of this kind meet some of the objections levelled at gross expenditure data, ultimately they do not represent any more than the amounts spent on services connected with the facilities, rather than on the facilities themselves.

4. To provide an answer to the question of what the recreational potential is 'worth' in a price or market sense, Marion Clawson[1] has suggested ways of estimating the demand for recreational opportunity. His method is to proceed in two stages, first establishing the demand for the 'total recreation experience', then deriving from this the demand for the 'recreation opportunity itself'.

5. The first stage, the total recreation experience, can be estimated by determining the proportion of a total population which has taken advantage of particular facilities. From figures of the numbers of visitors to certain sites and what are termed 'some rather heroic assumptions' about some of the costs, a monetary value can be put on each visit related to the distance travelled. From this it is possible to establish a relationship between the cost per visit and the number of visits for a given number of the population.

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[1] *Methods of Measuring the Demand for and Value of Outdoor Recreation, (Resources for the Future) to which paragraphs 2-7 are largely indebted.*

6. The second stage, the demand for the recreation opportunity itself, uses these relationships to show what the effect of various increases in entrance fees for the use of the facilities would be, assuming that the attitudes of visitors from one neighbourhood will reflect the attitudes of visitors from other neighbourhoods. From the data on estimated numbers of visits at each level of increased fees it is possible to establish within limits the relation between the number of visits and entrance fees, giving some means of measuring the willingness of visitors to pay measurable or definable sums of money for the use of a particular site.

7. A fourth possibility might be to explore the notion of 'consumer's surplus' in the context of recreational facilities. Since some visitors would be willing to pay more for the privilege of their visit than they are usually asked to do, they enjoy a benefit which may be described as a surplus. In practice it is difficult to see how such a surplus could ever be assessed, since it is only to be expected that however high the entrance fee, some visitors would still enjoy a surplus, apart from the problems of deriving the data which would make an estimate possible.

8. The foregoing survey of the various methods of evaluating recreational potential is brief but may be sufficient to indicate how very tentative are the known approaches to this problem, and how very controversial would be even the basic assumptions on which any value assessments might be founded. We have not attempted any such approach for two reasons. First, any of the proposals we have examined for conservation schemes would have involved a disproportionate amount of time and effort in preparing the necessary statistical foundation, particularly since none of the proposals has been taken to the state of detailed planning. An attempt to do so for all the sites considered would have been quite unmanageable in the time available. Secondly, our survey may serve to demonstrate that there is no approach that we could use with confidence in the expectation that it would be generally accepted. Had we attempted to evolve a variation on these methods, this might have produced an array of costs that would be quite misleading.

9. Instead, as we have explained in Chapter 6, we have set out the costs of alternative proposals which include or exclude developments in areas where, by general consent, proposals for new development should be scrutinised with particular care, as for example the areas designated as National Parks or 'of Outstanding Natural Beauty'. With present techniques and in the time at our disposal we have concluded that this is the most realistic approach possible.

10. The attraction of man-made lakes may be to a different section of the community and one which often plays little part in public debates on particular water proposals, but the fact remains that for many people a reservoir may create a new amenity, and in economic terms this is an increment to the national product in addition to that springing from its prime purpose. This is true whether the new reservoir is used as a source of quiet and passive recreation, a picnic site, an area for nature conservation and bird-watching or a place for pursuing active water sports.

11. The following paragraphs provide some indication of existing recreational facilities and attempt to show the order of costs and therefore benefits likely to be involved when reservoirs are used for recreation.

12. Existing recreational facilities are listed in Tables VI/E and are shown on Map 4 on a population density base. It will be noted that most of the present facilities are near to the centres of population. This is hardly

surprising since most of the existing reservoirs were developed as closely as possible to the centres of demand - see Chapter 2. In most cases the facilities which have been made available have been fully taken up.

13. The reports from many sources published in recent years (notably the final report of the Council of the Institution of Water Engineers on the recreational use of waterworks, the survey by the Central Council for Physical Recreation on the use of inland waters in the West Midlands, and the regional surveys of recreational facilities which are now being prepared or have been published by the Regional Sports Councils) provide ample evidence of the persistent demand for angling and particularly sailing among other recreational facilities on reservoirs.

14. Some indication of the growth in demand for sailing is provided by the growth in membership of sailing clubs. The membership of the Royal Yachting Association has grown from 722 in 1948 to 26,043 in 1968 and it has been estimated that the number of dinghy sailors has increased from about 1,000 in 1948 to 33,000 in 1968. If this remarkable rate of growth is considered in relation to the number of water supply reservoirs which could be made available for sailing since 1948, even taking account of the greater use being made of all other inland waters such as gravel pits, lakes and rivers, it is evident that when all the existing reservoirs are fully used there will still be a considerable demand which the new reservoirs might meet.

15. In general the new reservoirs would be located at some distance from the present centres of existing facilities. It might be argued that their greater distance from the centres of population will lessen their ability to meet the demand but a population which has more leisure, more wealth, improved transport and generally a greater willingness to travel may provide an entirely new factor of demand.

16. Whilst it seems clear that some recreational benefit would be derived from the new schemes, the problems referred to above make it difficult to estimate its extent. Before 1981 this is likely to be fairly small but a rough measurement would be the numbers of boats and sailors and of fishermen for each 1,000 acres of water surface. For schemes after 1981 when the recreational potential could be considerable some quantification could be made for one or two of the programmes we have suggested to permit some comparison with the recreational potential of developments in estuaries.

17. We have noted that much attention has been paid, particularly in the United States, to the problem of assessing the recreational benefits of particular sites, and its impact on the cost of water produced from them. The recreational value of facilities that people are accustomed to make some payment for, such as boating or angling, presents no great methodological problems, and evaluation, although it may be difficult in practice, is a question of market research. What is needed is an assessment of how many people are likely to use the reservoir and how much and what scale of charges the market will bear. For practical reasons we have been unable to conduct an investigation of this sort into the recreational potential of the new sites we have considered.

18. We have, however, examined the existing facilities at the Derwent (Co. Durham), Grafham Water, Pitsford, Fly Flats and Damflask reservoirs, and the details given in Tables A to D show, inter alia,

(a) The catchment population (i.e. the population within 25 miles).

(b) The area of the reservoir.

(c) An estimate of the number of users or expected users for sailing and/or fishing.

(d) The annual costs and income from sailing and fishing.

(e) The annual expenditure by individuals on recreation.

(f) The annual costs of water supply.

19. These figures enable us to make only very broad inferences, for they are only rough indicators of the factors we need to isolate. For sailing none of the cost and income figures can be said to provide an indication of the benefit because in no sense has a market for the commodity of sailing facilities been established. The administrative and institutional framework of sailing on reservoirs inevitably distorts the relationship between the facilities enjoyed and the price paid for them.

20. The costs shown at (d) themselves do no more than balance income against annual expenditure on the ancillaries to the recreation: boathouses, slipways, lavatories and so on; no economic price is paid for the facility of sailing itself. (Theoretically one might be derived using the method elaborated by Marion Clawson and mentioned in paragraph 8 above. Travel costs might serve as an indicator of price. But the relevant statistics are not available and it has not been possible to collect them.)

21. The figures referred to at (e) and shown on Table A1 at column (5) are an estimate of the total expenditure by individuals on sailing. The estimates include club subscriptions, travelling costs and depreciation on sailing craft. Some 40% of the expenditure therefore relates to the cost of owning a boat and is not considered relevant to our purpose. But 60% of this figure, representing expenditure on sailing at the particular reservoir plus the balance of the annual expenditure incurred by the controlling undertaking, gives some indication of the amounts being expended annually on sailing. While this cannot be regarded in any sense as a measure of the benefit, it provides a crude pointer to its existence. It is about 13% of the annual costs of the reservoir.

22. The figures for fishing (Tables B, B1 and D) are rather more revealing because a truer market for the recreational benefit has usually been established. The usual practice of the statutory water undertakings responsible is to balance income from licenses against the annual expenditure on maintenance (as indeed is true for sailing), but at Derwent, Damflaak and Grafham Water the annual income now exceeds maintenance expenditure and gives a useful indication of market value. On the assumption that this market value can be applied to the other reservoirs, it is possible to derive a fishery 'benefit' ranging from - 0.25% to 5% of the total reservoir costs with a mean of about 2%. This figure is not of course comparable with the sailing 'benefit' derived in paragraph 21. A fishery 'benefit' estimated on the same basis used there would range between 6% and 22% of the annual reservoir costs with a mean of some 10%.

23. In considering choices between alternative inland reservoir sites some measure of recreational benefit could be common to both sites and one of our basic assumptions is that all reservoirs can and should be used for multi-purpose activities, although sometimes the recreational activities will be quiet and passive rather than active. The variations in the recreational benefit would arise from the locality of the reservoir and its possible demand catchment. But the benefit as far as we have been able to assess it is already small in relation to the water conservation costs and the variations must be smaller still. Moreover these conservation costs are only about 20% of the total programme costs upon which a choice of strategy should be based.

24. From this we have concluded with some confidence that the differential in recreational benefits of the sites considered would not be large enough to influence this choice. They may, however, have some significance when further comparisons come to be made with proposals for developments in estuaries. It may then be appropriate to make a more detailed appraisal of the combined recreational potential of the various inland schemes.

TABLE A SAILING

STATISTICS FOR CERTAIN RESERVOIRS WHICH PROVIDE RECREATIONAL FACILITIES

Reservoir (1)	Area Acres (2)	Population within 25 miles Million (3)	Avg. No. participating or expected to participate (4)	Capital expenditure to provide sailing £ (5)	Per Capita capital expenditure £/head (6)	Annual Cost including 8% interest on Capital required £ (7)	Per Capita Annual Costs £/head (8)	Annual Income from fees and subscriptions £ (9)
Derwent	1,000	1.8	1,000	70,000[1]	70	9,600	9.6	3,544
Grafham Water	1,500	1.0	1,750	78,000[1]	45	23,600	13.5	18.750
Pitsford	486	1.0	800	11,000	14	3.500	4.4	3.594
Fly Flats (Halifax)	80	4.0	165	2,400	14.5	400	2.4	540
Damflask (Sheffield)	115	3.5	200	5.750	29	520	2.6	1.600

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[1] *Including grants.*

TABLE A1

ESTIMATE OF TOTAL EXPENDITURE ON SAILING

Reservoir	Annual Cost	Fees & Subscriptions	Annual Expenditure less income (2 − 3)	Total Individual Expenditure on Sailing	60% of (4)	Expenditure on Sailing at the reservoir (4 + 6)	Annual Cost of water supply	Expenditure on sailing expressed as a percentage of water cost
	£	£	£	£	£	£	£	
	A(7)	A(9)				D(2)	C(3)	$\frac{(7)}{(8)} \times 100\%$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Derwent	9,600	3,544	6,056	20,000	12,000	18,056	375,000	5%
Grafham Water	23,600	18,750	4,850	52,000	31,200	36,050	212,000	18%
Pitsford	3,500	3,594	− 94	16,000	9,600	9,506	122,000	8%
Fly Flats	400	540	− 140	11,000	6,600	6,460	18,600	35%
Damflask	520	1,600	− 1,080	11,500	6,900	5,820	175,000	3%

TABLE B ANGLING

STATISTICS FOR CERTAIN RESERVOIRS WHICH PROVIDE RECREATIONAL FACILITIES

Reservoir (1)	Average No.[1] participating or expected to participate (2)	Capital expenditure including original stocking £ (3)	Per Capita capital expenditure £/head (4)	Annual Costs including annual re-stocking and interest on capital £ (5)	Per Capita annual costs £/head (6)	Average No. of rod/days per year (7)	Average Cost per rod/day £ (8)	Annual income from fees and subscriptions £ (9)	Annual Income less expenditure £ (10)	Column (10) as a percentage of water supply cost % (11)
Derwent	500	9,000	19	6,600	13	10,200	0.65	8,320	1,720	0,46
Grafham Water	1,000	34,000	34	25,000	25	23,000	1,1	36,500	11,500	5.4
Pitsford	200	11,820	59	5,145	26	3,900	1,3	4,843	− 302	− 0,25
Damflask (Sheffield)	500	1,000	2,0	3,000	6,0	30,000	0,1	4,800	1,800	1,0

[1] *Estimated from data in Col. 7.*

TABLE B1

ESTIMATE OF TOTAL EXPENDITURE ON FISHING

Reservoir (1)	Annual expenditure on fees, subscriptions and R.A. licences £ (2)	Additional expenditure by Authority where applicable £ (Deficits in B10) (3)	Travelling expenses £ (4)	Total Expenditure on fishing £ (2)+(3)+(4) D(3) (5)	Annual cost of water supply £ C(3) (6)	Expenditure on fishing expressed as a percentage of water cost $\frac{(5)}{(6)} \times 100\%$ (7)
Derwent	8,820	NIL	13,800	22,620	375,000	6%
Grafham Water	37,100	NIL	10,000	47,100	212,000	22%
Pitsford	5,043	302	1,500	6,845	122,000	6%
Damflask	5,100	NIL	7,050	12,150	175,000	7%

TABLE C

WATER SUPPLY FINANCE

Reservoir (1)	Capital Cost equated to circa 1965 £m. (2)	Annual costs including interest on capital at 6.7% £ (3)	Yield m.g.d. (4)	Storage cost Pence per thousand gallons of yield (5)
Derwent	5.5	375,000	30.0	8.1
Grafham Water	3.15	212,000	40.5	3.4
Pitsford	1.82	122,000	8.0	10.0
Fly Flats (Halifax)	0.28	18,600	1.25	9.8
Damflask (Sheffield)	2.6	175,000	4.53	25.0

TABLE D

ESTIMATE OF COMBINED TOTAL EXPENDITURE ON RECREATION

Reservoir (1)	Sailing expenditure £ A1(6) (2)	Fishing expenditure £ B1(5) (3)	Combined expenditure Sailing and fishing £ (1)+(2) (4)	Annual cost of water supply £ C(3) (5)	Combined expenditure on sailing and fishing expressed as a percentage of water cost $\frac{(4)}{(5)} \times 100\%$ (6)
Derwent	18,056	22,620	40,676	375,000	11%
Grafham Water	36,050	47,100	83,150	212,000	39%
Pitsford	9,506	6,845	16,351	122,000	13%
Damflask	5,820	12,150	17,970	175,000	10%
Fly Flats	6,460	Nil	6,460	18,600	35%

TABLE E

PRESENT RECREATIONAL USE OF RESERVOIRS

No.	Reservoir	Grid Ref.	Area Acres	MAJOR USES				SUBSIDIARY USES		
				Sailing			Angling			
				Year sailing commenced	Av. No. of members	Av. No. of boats in club		Bird Watching	Rambling	Sub Aqua
Statutory Water Undertaking Reservoirs										
1	Oerwent	NZ 020 520	1,000	1967	700 rising	170 rising 400 limit				
2	Tunstall	NZ 065 410	66	No present use but has been tried for sailing in past						
3	Killingsworth	NZ 275 710	17.6	Sailing (teaching)						
4	Harlock	SO 248 793	35				X			
5	High Newton (2)	SD 399 843	6 } 10 }				X X			
6	Ireleth	SD 225 776	5				X			
7	Ormsgill (2)	SD 195 710	45				X			
8	Pennington	SD 257 790	27				X			
9	Poaka Becks	SO 243 783	24				X			
10	Pedderpots	SO 534 705	15				X			
11	Anglesarke	SO 615 165	197				X			
12	Bracken Lea	SO 525 484	14				X			
13	Rake Brook	SO 646 222	15				X			
14	Rivington (2)	SD 625 135	218 } 56 }				X X			
15	Yarrow	SO 625 155	62				X			
16	Cant Clough	SD 895 309	41				X			

TABLE E

PRESENT RECREATIONAL USE OF RESERVOIRS

No.	Reservoir	Grid Ref.	Area Acres	MAJOR USES				SUBSIDIARY USES		
				Sailing			Angling			
				Year sailing commenced	Av. No. of members	Av. No. of boats in club		Bird Watching	Rambling	Sub Aqua
17	Churn Clough	SD 785 383	17				X			
18	Clowbridge	SD 824 281	79	1966	100	45				
19	Dean	SD 715 330	50				X			
20	Earnsdale	SD 670 222	18				X			
21	Foxhill Bank	SD 740 280	5				X			
22	Greenfold	SD 822 262	14				X			
23	Higher Antley	SD 745 282	10				X			
24	Higher Blackmoss	SD 824 412	12				X			
25	Hoddlesden	SD 716 227	14				X			
26	Jackhouse	SD 743 260	11				X			
27	Lea Green	SD 880 338	8				X			
28	Lower Antley	SD 745 280	9				X			
29	Lower Blackmoss	SD 828 415	17				X			
30	Mitchell House (2)	SD 790 275	11) 19)				X X			
31	Ogden	SD 765 226	53				X			
32	Warmwithens	SD 740 245	10				X			
33	Walverden	SD 872 365	8				X			
34	Appleton	SJ 602 843	19				X			
35	Arley	SD 583 110	19				X			

TABLE E

PRESENT RECREATIONAL USE OF RESERVOIRS

No.	Reservoir	Grid Ref.	Area Acres	MAJOR USES				SUBSIDIARY USES		
				Sailing			Angling			
				Year sailing commenced	Av. No. of members	Av. No. of boats in club		Bird Watching	Rambling	Sub Aque
36	Pemberton No. 1	SD 532 035	7				X			
37	Pemberton No. 2		6				X			
38	Worthington	SD 583 105	15				X			
39	Belmont	SD 673 164	97	1953	333	92				
40	Brushes	SK 000 990	8				X			
41	Delph	SD 703 154	72	1960	135	37				
42	Dovestone (Yorks)	SE 015 035	82	No details						
43	Entwistle	SD 723 173	94				X			
44	Gorton Upper	SJ 900 960	30	1960	100	50	X			
45	Gorton Lower		19				X			
46	Hollingworth	SD 934 146	118	1937/1946	300–400	65 limit	X			
47	Kitcliffe	SD 960 125	12				X			
48	Knott Hill	SD 958 013	14				X			
49	Lower Castlehew	SD 985 107	26				X			
50	Lower Dukinfield	SJ 956 972	6				X			
51	Ogden	SD 953 125	31				X			
52	Rumworth	SD 673 083	33				X			
53	Strinesdale Upper	SD 957 068	12				X			
54	Strinesdale Lower	SD 957 065	16				X			
55	Walker Wood	SJ 986 990	27				X			

TABLE E

PRESENT RECREATIONAL USE OF RESERVOIRS

No.	Reservoir	Grid Ref.	Area Acres	MAJOR USES				SUBSIDIARY USES		
				Sailing			Angling	Bird Watching	Rambling	Sub Aqua
				Year sailing commenced	Av. No. of members	Av. No. of boats in club				
56	Waych	SD 736 163	117				X			
57	Bottoms Macc.	SJ 946 716	10				X	X		
58	Bottom Tintwistle	SK 027 970	49				X			
59	Teggsnose	SJ 946 718	5				X			
60	Valehouse	SK 035 975	44				X	X		
61	Fly Flats	SE 030 315	68	1959	130	60				
62	Boshaw Whams	SE 152 057	5	1958		20 limit	X		X	
63	Cold Acre	SE 071 169	2				X	X		
64	Crowhole	SK 320 748	8.1				X	X		
65	Damflask	SK 278 906	115	1961	186	70	Bank) only)	X	X	
66	Fewston	SE 188 642	156				X	X	X	
67	Green Withens	SO 989 164	53	1962		50 limit				
68	Holmestyes	SE 141 056	8.5				X			
69	Ilton	SE 183 777	6¼				X	X	X	
70	Leighton	SE 164 788	105				X	X	X	
71	Linacre Lower	SK 337 725	8.5				X	X		
72	Linacre Middle	SK 333 725	17.1				X	X		
73	Linacre Upper	SK 327 727	18				X	X		
74	Lindley Wood	SE 218 487	117				X	X	X	
75	Mixenden	SE 060 289	21¼				X	X	X	

TABLE E

PRESENT RECREATIONAL USE OF RESERVOIRS

No.	Reservoir	Grid Ref.	Area Acres	MAJOR USES				SUBSIDIARY USES		
				Sailing			Angling			
				Year sailing commenced	Av. No. of members	Av. No. of boats in club		Bird Watching	Rambling	Sub Aqua
76	More Hall	SK 280 960	65	1952	102	65		X	X	
77	Reva	SE 152 427	16⅓	1968						X plus canoeing
78	Ryburn	SE 010 187	26							
79	Scout Dike	SE 234 047	38				X	X		
80	Swinsty	SE 196 528	156				X	X	X	
81	Thruscross	SE 155 575	142	1969			X	X	X	
82	Underbank	SK 245 995	103	1959	66	40	X	X	X	
83	Walshaw Dean Lower	SD 961 332	24½				X	X	X	
84	Walshaw Dean Middle	SD 968 337	38				X	X	X	
85	Walshaw Dean Upper	SD 968 345	24¾				X	X	X	
86	Warley Moor	SE 031 317	68	1969	162	75	X	X	X	
87	Widdop	SD 931 329	93¼				X	X	X	
88	Aled Isaf	SH 913 595	70				X			
89	Alwen	SH 945 537	380				X			
90	Bala	SH 915 342	1,000	1958	260+	170	X			
91	Brithdir	SJ 179 627	3				X			
92	Bryn Mulan	SJ 059 628	2				X			
93	Cilcain (2)	SJ 156 642 SJ 166 642	) 16)				X			
94	Dolwen	SH 973 704	30				X			

TABLE E

PRESENT RECREATIONAL USE OF RESERVOIRS

No.	Reservoir	Grid Ref.	Area Acres	MAJOR USES				SUBSIDIARY USES		
				Sailing			Angling	Bird Watching	Rambling	Sub Aqua
				Year sailing commenced	Av. No. of members	Av. No. of boats in club				
95	Llyn Aled	SH 915 575	110				X			
96	Llyn Celyn	SH 855 405	830				X			
97	Llyn Cyfynwy	SJ 217 547	20				X			
98	Nant y ffrith	SJ 243 530	15				X			
99	Pendinas	SJ 236 518	23				X			
100	Penycae	SJ 272 454	25				X			
101	Plas Uchaf	SH 969 713	10				X			
British Waterways Board reservoirs										
201	Barrowford	SD 870 399	16				X			
202	Bosley	SJ 920 660	78				X			
204	Carr Mill	SJ 525 976	52	X			X	X	X	X
205	Coombs	SK 035 797	66	1950		35	X			
206	Elton	SD 791 093	55	1858	310	110	X			
207	Foulridge Lower	SD 881 419	87	1960		50 approx	X			
208	Foulridge Upper	SD 895 414	32				X			
209	Hurleston	SJ 622 554	19				X	X		X
210	Killamarsh	SK 473 809	4½				X		X	
211	Killington	SD 590 910	154	1957		45	X			
212	Redbrook	SE 027 099	18	1961		60			X	

TABLE E

PRESENT RECREATIONAL USE OF RESERVOIRS

No.	Reservoir	Grid Ref.	Area Acres	MAJOR USES				SUBSIDIARY USES		
				Sailing			Angling	Bird Watch-ing	Rambling	Sub Aqua
				Year sailing commenced	Av. No. of members	Av. No. of boats in club				
213	Rishton	SO 715 300	33	1959	32	18	X			
214	Slaithwaite	SE 075 141	12				X		X	
215	Slipper Hill	SO 875 420	13	1 boat			X			
216	Southfield	SE 652 191	117	1959	250	150	X			
217	Sparth	SE 056 125	3				X			
218	Sutton	SJ 919 701	15	X		28 limit	X			
219	Toddbrook	SK 005 810	39	1958		58	X			
220	Winterburn	SD 945 601	39				X		X	
221	Woodhall	SK 477 810	7				X		X	

APPENDIX VII

APPENDIX VII: USE OF CANALS

The Canal System

1. In the southern half of the study area there is a network of canals, for the greater part constructed in the course of the industrial revolution. Apart from the Manchester Ship Canal, the Bridgewater and the Rochdale Canals, they are owned and managed by the British Waterways Board (referred to in this appendix as 'The Board'). In addition, there are a number of river navigations for which the Board is the navigation authority.

2. The Board's waterways within the study area include the Ripon, the Pocklington, the Huddersfield, the Lancaster, the Leeds & Liverpool, the St. Helens, the Manchester, Bolton & Bury, the Ashton, the Peak Forest and the Macclesfield Canals and the Ure, Aire & Calder, Calder & Hebble, Sheffield & South Yorkshire and Weaver Navigations in their entirety, together with parts of the Chesterfield, the Trent & Mersey and the Shropshire Union Canals. The total length of these canals is nearly 400 miles and of the river navigations is over 130 miles.

3. Over the years their contribution to industrial water supplies and to various forms of amenity has increased. Publications dealing with the amenity use of canals will be found in the bibliography; the amenity use of canal reservoirs is referred to in Appendix VI.

4. The extent of the water supplied for industrial purposes is indicated by the licences for abstraction granted by the northern river authorities under the terms of the Water Resources Act, which in the case of abstractors from the independent waterways amount to 300,000 m.g.a.,[1] almost all of which is returned to the waterway. Abstractions from river navigations for which the Board is the navigation authority total 266,000 m.g.a. and from the Board's canals 23,000 m.g.a. The major part of these abstractions is returned to the waterway: a study of the Board's canals in the area of one river authority showed that the proportion was nearly 80%.

5. Canals can depend for their water resources upon their own natural catchment, infiltration (especially in tunnels), feeders from streams and rivers, mine water, boreholes, purified effluent and reservoirs. The Board owns 27 reservoirs in the study area, including Todd Brook, the earliest high (50 ft. or more) dam to be constructed in this country. The total storage of these reservoirs is 3,860 m.g., including three balancing reservoirs, and their total catchment amounts to just under 32,000 acres. Their reliable annual yield is about 8,000 m.g.

6. The natural catchment of canals is rather less determinate, particularly in built-up areas, but the magnitude of run-off can often be assessed inferentially by a study of the fluctuation in flow at different points on a canal relative to local rainfall. A detailed study of one of the Board's major canals showed that its direct natural catchment contributed 27% of its resources in a typical year compared with 51% from surface water feeders, 3% from mine water and 19% from reservoirs.

7. The availability of supplies from the canals for industrial purposes is governed by the same basic considerations discussed in relation to Industrial Rivers in Appendix II. Existing resources are not at present fully utilised. Additional non-returned supplies could be made available to a limited extent, dependent upon the resources of the particular section, and there is scope for an

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[1] *Million gallons per annum*

increase in returned supplies dependent upon net use and the quality of the returned effluent. In the latter respect the Board is taking active steps to eliminate pollution as set out in their Annual Report for 1967. Canals have a greater capacity to dissipate heat than natural streams of comparable flow and present supplies of water abstracted for direct cooling could be much increased within the limits of acceptable temperature rise.

8. Apart from the supply of water from their own resources, there are instances of canals being used to convey water for statutory water undertakers. The extent to which water can be conveyed along a canal by the use of its natural gradient is governed by the length of its pounds (i.e. the distance between locks) and the freeboard available.

9. In operating a canal in this way a number of engineering considerations arise, including the maintenance of the channel by dredging, the protection of the banks against erosion, the control of weed growth, the effect of ice formation, the disposal of storm water and provisions for dealing speedily with emergencies.

10. In the context of the Working Party's deliberations there are two canals in the study area which might be able to play a part in the conveyance of bulk water supplies, the Leeds & Liverpool Canal and the Lancaster Canal.

The Leeds and Liverpool Canal

11. The Leeds & Liverpool Canal from its most northerly point at Gargrave falls eastwards over a distance of 35 miles, and 323 feet vertically through 35 locks, to join the River Aire at Leeds. The lengths of the pounds vary from a few yards up to 17 miles. If large quantities of water are to be conveyed from sources in the west to the West Riding of Yorkshire, there could be advantage in passing part of this, for local use, down to Leeds by way of the canal, which is less contaminated than the River Aire as it approaches the city. Typical analyses by the river authority have shown a B.O.D. of 1.5 p.p.m. in the canal at Leeds compared with a figure of 9.2 p.p.m. in the River Aire. Corresponding figures for ammoniacal nitrogen were 0.02 p.p.m. and 4.92 p.p.m. respectively.

12. All the different types of water resource instanced in paragraph 5 contribute, in varying degrees, to meeting the demands upon the canal. These demands are principally for lockage arising from the use of the canal for pleasure cruising, for industrial water supply, and for seepage and evaporation losses. Where water is required to pass along the canal to meet these latter needs, in excess of lockage, it passes around the locks by means of byweirs.

13. If additional quantities of water were to be conveyed they would pass over the existing byweirs, which would need to be lengthened. Above a conveyance of 15 m.g.d. interval pumping would have to be introduced in the longer pounds: this concept is explained in paragraph 16. The costs of conveyance of such larger quantities would be substantially less than those for the Lancaster Canal as set out in paragraph 26.

The Lancaster Canal

14. The Lancaster Canal, by reason of its location, invites examination for the conveyance of water in this way. It covers a length of 49 miles from Stainton (near Kendal) in the north to Preston in the south. From Stainton to Tewitfield Locks (8½ miles) the canal acts as a water channel to the south for supplies arising from the Board's reservoir to Killington and from surface water

feeders. It continues from Tewitfield to Preston in one long pound for 41 miles, its water resources being further augmented by feeders. From this point a 2¾ mile branch leads down to the Glasson Basin from which access can be gained to the River Lune.

15. Attention has been given principally to the conveyance of water in a southerly direction along the main pound. About 400 pleasure craft are licensed on the canal at the present time, and its present depth and cross-section is somewhat less than was needed at the time of commercial navigation. The canal is clay-lined over much of its length, so that the original cross-section could not be exceeded, but dredging should enable it to convey, in addition to the canal's own operational requirements, about 8 m.g.d. within a gradient based upon a 12-inch reduction of water level at the downstream end.

16. Flows larger than this could be conveyed along the pound by the construction of intermediate stop-locks and associated pumping stations at intervals along its length. These pumping stations would lift the water 12 inches at each stop-lock, so steepening the gradient and increasing the flow. The frequency of installation of pumping stations along the pound to provide for different rates of flow is shown on the accompanying graph (fig VII/1)

17. To predict the gradients corresponding to particular rates of flow it was essential to know the coefficient of roughness of the canal as accurately as possible and arrangements were made to determine this. It was not possible for a number of reasons to pass flows along the Lancaster Canal of the magnitude required for the necessary measurements of gradient. Observations were therefore made on the Leeds & Liverpool Canal, using its summit level as a reservoir. A flow of 50 m.g.d. was passed along a 7-mile length of the canal and as a check a flow of 26 m.g.d. along a 24-mile length of the canal. Flow measurements were taken at calibrated lock-paddles, supplemented by rod float runs in bridgeholes. As a result of this work, a value of 40 $m^{1/6}$ was derived for the Chezy coefficient.[1]

18. Provision for interval pumping at the larger flows, referred to above, has been made in the cost estimates which follow. Pumping stations would house two electrically powered pumps, together with a standby diesel generator. It is envisaged that the pumping stations would be connected by landline to a central control room which would be manned day and night. Costs have been developed on the basis that a selected conveyance scheme would be worked at full capacity; a scheme which was not operating at near-maximum capacity would involve correspondingly higher unit costs. A system could, however, be built up economically in stages from an initial station halfway along the pound; then two stations at the quarter points; then four stations at the eighth points, and so on. The levels and arrangement of existing storm weirs might need to be modified or supplemented, but this would have to be studied in the context of a specific scheme.

19. Provision has also been made in the cost estimates for maintenance dredging at more frequent intervals than is normally necessary and for bank strengthening work to reduce the risk of breaches still further. The control of

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[1] *C in the formula* $v = c\sqrt{mi}$ *where:-*

v = *mean velocity of flow*
i = *hydraulic gradient*
m = *cross-sectional area of flow divided by wetted perimeter*

seasonal weed growth is essential in order to permit the use of the full cross-sectional area of the canal and allowance has been made for this as well.

20. Mention has already been made of the use of the canal by pleasure craft; the adoption of channel velocities which might appreciably affect the movement of craft would require an alteration of the law as at present existing. Provided that the velocity of flow in the open canal does not exceed 1 foot per second, it is thought that their movement should not be seriously hindered. This velocity corresponds to a conveyance of approximately 60 m.g.d.

21. It is perhaps appropriate to comment on the canal's resources for water supply and on their quality. The Lancaster Canal is fed by the Board's Killington Reservoir and by four feeders. The reliable yield of the reservoir is about 4 m.g.d. and when supplemented by the canal feeders and natural run-off direct to the canal from adjoining land provides a useful source for certain industrial water supplies. As with all canal reservoirs, the demand upon it for traffic purposes is relatively small during the winter months, and at its maximum in a dry spell when the yield from feeders is reduced. Losses by seepage and evaporation on the Lancaster Canal at about an inch per day on the water surface or 6 m.g.d. are typical of most artificial canals. Such losses are largely made up by run-off from the canal's natural catchment. There is no reason to suppose that conveyance of water in the manner proposed would affect the existing losses or that these would prove a source of difficulty.

22. The quality of the canal water is fairly good and at the point where it crosses over the River Lune is broadly similar to the river water. A typical analysis shows a chloride content of 20 p.p.m. compared with 15 p.p.m. in the river. The corresponding figures for total hardness are 153 p.p.m. and 86 p.p.m. These characteristics would, of course, change towards those of the greater quantities of water imported into the canal from outside sources.

23. Water is required solely for lockage only in the Glasson Branch and the amount is small enough at the present time to be ignored. If it were to increase to significant proportions, the recovery of lockage water could be achieved by back-pumping to the head of the locks. There are a number of industrial water abstractions from the main canal of which the principal one is a non-returned supply of up to 3 m.g.d. with provision for a greater quantity in certain circumstances.

24. In canal work the possibility of a breached bank has to be considered and an emergency of this kind is met by holding a supply of large diameter pipes at a central point to enable the breach to be by-passed until restoration work is complete. To ensure continuity of supply it may be desirable to provide additional raw water storage at the point of abstraction. It is estimated that one day's storage could add 0.005d/1000 gal./mile to conveyance costs.

25. The position which would result from a period of severe icing such as occurred in the winter of 1963 has also been assessed, based upon experience gained in that year on the Llangollen Canal. This canal has been used for a number of years for the conveyance of water from the River Dee near Llangollen over a length of 46 miles to Mid-Cheshire. Although 12 inches of ice formed on the canal in that year, there was no substantial reduction in the rate of supply to the Water Board as a result. The frequency of recurrence of a winter as severe as this is low but an assessment has been made of the effect of ice formation on a conveyance scheme. The effect is to convert the canal to a closed conduit having differing roughness characteristics, and it is estimated that the flow might be reduced by about 30% under these conditions.

26. The Board's charges for conveying water would, of course, depend upon the circumstances of each case, but it estimated that the net costs would be of the following order. The estimates are based on mileage measured along the canal, because on any other basis assumptions would have been necessary as to the geographical length over which conveyance was to take place compared with a pipeline alternative.

Quantity conveyed in excess of canal requirements	Cost per 1,000 galls. per canal mile
20 m.g.d.	0.04 pence
50 m.g.d.	0.07 pence
75 m.g.d.	0.12 pence

27. Although the cost figures have been related to the length below Tewitfield Locks, the special problems which would arise in the length above Tewitfield have also been examined. It is thought, however, that these special features would not add materially to the conveyance costs per mile of canal if the scheme were to be extended to include the full length of the canal.

Future Uses

28. From possible sources north of the River Lune at Lancaster to the termination of the Lancaster Canal near Preston Canal mileage is approximately 1.3 times the direct pipeline mileage. Transmission costs comparable with the costs of delivery by pipeline would thus be approximately 0.06 pence/1000 gals./mile at 20 m.g.d. to 0.16 pence/1000 gals./mile at 75 m.g.d. At the higher flow rate the estimated costs of transmission by canal or pipeline are approximately the same.

29. Thus when considering bulk transport of large quantities of water in the regional transmission networks envisaged in the programmes described in Chapter 7 use of the Lancaster Canal would not show any significant savings in the total costs based upon pipeline networks. Some local savings may be possible in elements of the regional schemes serving the Fylde and Preston areas. The most likely use of the Lancaster Canal would seem to be as part of an integrated supply system combining river abstractions with controlled development of underground storage in the Fylde and Preston areas referred to in Appendix V.

30. In the case of the Leeds/Liverpool Canal an alternative natural transmission link exists in the River Wharfe which has been used for all east to west transfers in our programmes of development. Any savings in the use of the canal would be largely of local significance in shortening the final transmission distance between the ultimate abstraction point and some individual service reservoir locations in the West Riding.

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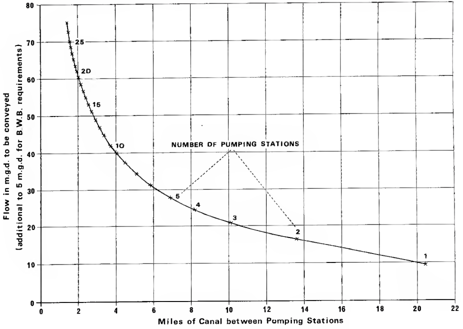
CONVEYANCE OF WATER BY CANAL

LANCASTER CANAL 41 MILE MAIN POUND DREDGED TO ORIGINAL CROSS SECTIONAL AREA



APPENDIX VIII

APPENDIX VIII: UNIT COSTS

1. Chapter 4 describes how all the potential resources have been assembled in the summary schedules in Appendix IX with an estimated unit cost in pence per thousand gallons of water treated and delivered into terminal storage at various notional demand centres within the command area of each source. The preliminary unit costs calculated for this purpose are given in Table VIII/2 and the loan periods and interest rates assumed for the purpose of the calculations in Table VIII/1. On the basis of this crude data computer selections of resources were made, with and without constraints, to narrow the field of choice to a smaller number of alternatives upon which the detailed programmes of development were based.

2. In costing these development programmes with actual capital and annual maintenance expenditure more refined costing was required which would take into account variations in cost with size. During 1966-67 the Water Research Association (W.R.A.) carried out a survey and analysis of water supply costs on behalf of the Water Resources Board in connection with a study of the comparative costs of desalination (W.R.A. T.P.60 1967). From a study of these analyses together with other recent costs and estimates we derived the costing rates given in Table VIII/3 and the cost graphs shown in Diagrams VIII/1-9 as follows:-

3. **Earth Dams**

Diagram VIII/1 shows the embankment quantity/cost relationship established in the W.R.A. analysis and for comparison the 30/- per cubic yard unit cost adopted in Table VIII/2 together with some individual costs and recent consulting engineers' estimates for specific projects. In the W.R.A. analysis the costs used were the total construction costs including immediate ancillary works but excluding land, diversion works, engineering and interest during construction. Adding 12½% to the W.R.A. curve to cover engineering and interest during construction gave curve C which we have adopted for final costing, land and diversion works being added at the rates given in Table VIII/2. Curve C is reproduced in Diagram VIII/2 together with a derived graph of unit cost v.s. volume of fill which varies from £2 per c.y. at 1/2 million c.y. of fill to 23/- per c.y. at 10 million c.y. of fill. For major projects staged constructions costs have been calculated based on these unit rates but including all sub-surface works for the final development in the Stage I costs.

4. **Concrete Dams**

A similar cost/quantity curve has been derived from the W.R.A. analysis for concrete gravity dams and is shown in Diagram VIII/3 and this has been applied in the few instances when a concrete section has been the obvious selection.

5. **Pumping Stations**

In their analyses of over 30 pumping stations the W.R.A. were unable to establish a good relationship between the total cost of pumping stations and any related feature such as total installed H.P. or throughput and concluded that much of the dispersion of data was attributable to the highly variable costs of the pump-house structures. A reasonable relationship was however, established between the costs of pumps, drives and ancillary electrical equipment and total installed horse-power. This would seem to confirm the validity of the approach adopted in our unit costs (Table VIII/2) of assessing the costs of pumping machinery and associated equipment separately from the cost of buildings.

6. Pumping Machinery

In Diagram VIII/4 the W.R.A. relationship between cost and installed horse-power has been expressed as a cost per water horse-power of normal duty assuming 50% standby pumping capacity and 70% overall efficiency. To this is added the estimated cost of screening plant, pipework, valves, etc. within the pump-house at rates varying with capacity from £24 per W.H.P. at 1,000 to £10 per W.H.P. at 4,000 W.H.P. Standby diesel alternators have been included at rates varying from £45 per KVA at 450 KVA to £35 per KVA at 6,000 KVA. 20% is then added for engineering, contingencies and interest to give a curve of final cost of machinery installed as in Diagram VIII/4. The curve indicates that the capital cost adopted in Table VIII/2 is adequate for stations with working capacity in excess of 3,000 W.H.P. but for smaller stations higher rates of cost per W.H.P. will probably be incurred. For final costing, rates per water horse-power have been taken from Diagram VIII/4.

7. Pumping Station Building

Data from the water supply cost study revealed little more than a high degree of variability in the costs of pumping stations in relation to load or duty. Final design is obviously dictated by considerations other than engineering requirements.

The following representative rates have been used in final costings:-

from £3,000 per m.g.d. up to 10 m.g.d. working capacity
to £2,000 per m.g.d. at 60 m.g.d. working capacity and above.

8. Pipelines

The unit cost in Table VIII/2 was derived from costing rates of 20/- per inch of diameter per linear yard at 24" diameter to 30/- per inch of diameter per linear yard at 96" diameter illustrated as total costs per mile by curve A of Diagram VIII/6. For comparison with this curve the diagram also includes curves based on data obtained from the W.R.A. analysis, Binnie's Great Ouse report 1965 and an analysis by the C.E.G.B. in 1965.

9. The indications from this supplementary data are that the rate of 20/- to 30/- per inch per yard is slightly high for all diameters. Most weight should obviously be attached to the W.R.A. analysis of actual costs of some 150 pipelines with data well distributed between pipe diameters of 8 to 48 inches. However, this analysis included only a limited number of cases extending up to 60 inch diameter, and the validity of extrapolating the data beyond 48" pipelines may be questioned. Additionally, for high heads and diameters over 48 inches pipelines would almost certainly be of steel and the relationship established in the W.R.A. analysis was based on data for all types of material. Thus the true cost relationship for steel pipelines may have been obscured by the weight of all the additional data in the smaller sizes. Analysis of the costs of steel pipelines only from the W.R.A. survey showed a fairly wide dispersion of data but a general trend towards increasing costs from 36" dia. upwards, the curve diverging from curve B to curve A over the range 36" x 72" dia.

10. For final costing we have therefore adopted curve E on fig. 6 and the corresponding rates in Table VIII/4. When determining pipeline sizes for particular schemes we have in general determined the optimum capacities and duplication points from consideration of economic pumping velocities.

The resultant capacities, replication points and mean friction losses at full and partial load factors are given in Table VIII/4. Diagram VIII/7 shows the optimum capacities and corresponding head losses together with an equivalent unit transport cost which includes pipeline and pumping charges.

11. **Treatment Works**

The W.R.A. analysed the costs of 22 recent 2-stage treatment plants and established a relationship between total capital cost and capacity. Modified to allow for interest during construction this relationship is shown in Diagram VIII/8. In preparing programmes of development assumptions about the capacity of treatment works for particular supplies to specific destinations must be arbitrary until schemes are finally designed in detail. Appendix IV suggests that the cost of the basic treatment plant would be similar for all river regulated sources. Thus the choice between alternative sources should not be affected by the cost of this plant and our programmes of development should not reflect differences due to arbitrary decisions on plant capacity. For these reasons we have assumed that for any pattern of demand treatment plant will be installed in equal increments over the period of development at an average cost of £50,000 per m.g.d.

12. In arriving at their unit treatment costs the water quality sub-committee concluded that in purpose-designed plant softening could be carried out in the sedimentation tanks and that for such plants capital cost would be about £55,000 per m.g.d. The percentage of total cost attributable to the softening process was not specifically stated. This could amount to £5,000 per m.g.d. The data in the W.R.A. analysis included five plants where softening was part of the process, and in all these cases the total capital cost lay within the upper range of 80% confidence limits of the statistical mean relationship. Thus an addition to the estimating rates would appear to be justified if softening is to be undertaken and we have added £5,000 per m.g.d. to the total capital cost in these cases.

13. **Service Reservoirs**

Diagram VIII/9 shows the relationship established by W.R.A. modified only to take account of interest during construction. A large quantity of data was analysed and the relationship was subject to only slight dispersion of the data and may be accepted as a reliable estimator of the costs of conventional covered service reservoirs with a division wall. The provision of terminal storage is directly related to the pattern of demands and is independent of the location or choice of sources. In comparing alternative programmes of development for any given pattern of demands we have therefore provided for terminal storage in annual increments, following the demand curve, at a representative price of £35,000 per m.g.

14. **Estuarial Schemes**

In these cases the capital costs assumed have been taken from the Consulting Engineers' reports on the desk studies as follows:-

Solway:	Stage	I	Yield	380	m.g.d.	Capital	Cost	£6m.
Morecambe:	Stage	I	"	250	"	"	"	£16.7m.
	"	II	"	200	"	"	"	£14.7m.
Dee:	Stage	I	"	50	"	"	"	£8.3m.
	"	II	"	50	"	"	"	£3.6m.
	"	III	"	100	"	"	"	£7.6m.
	"	IV	"	100	"	"	"	£9.3m.

15. **Maintenance Expenditure**

The amount of data available from the W.R.A. survey on maintenance and operating costs of pumping stations or treatment works was very limited in comparison with the data on capital costs - too limited to establish meaningful relationships. As power costs are the largest single variable element in maintenance charges the data from the W.R.A. survey has been replotted in Diagram VIII/5 in terms of pence per 1,000 gals. per 100 ft. lift against W.H.P. (assuming overall efficiency 70%) for comparison with the unit cost of 0.8d per 1,000 gals. adopted for the preliminary analysis. The limited data indicates an average power cost of 0.65d for all pumping stations of capacities in excess of 150 W.H.P. and would seem to confirm the adoption of a figure of 0.8d including maintenance of machinery and any capital contribution to power supply as a reasonable estimating figure for normal pumping duties. The W.R.A. analysis of costs of maintenance and operation of treatment works was considered by the water quality sub-committee in arriving at their estimates of unit treatment costs which we have adopted for final costing.

16. **Programme Costs**

It must be emphasised that the detailed analyses used to derive the final costing rates in Table VIII/3 should not be taken to imply great accuracy in the overall programme costs quoted in Chapter 7. Little is yet known of the sources suggested as possible developments and the exact location and capacity of pumping stations, pipelines, treatment works and service reservoirs cannot be determined until schemes are investigated and designed in detail. In the absence of this detailed knowledge general assumptions have been made, more or less common to all programmes, which have been aimed at producing representative costs which will truly reflect the differences between alternative programmes. Within these assumptions costing rates have been based upon the most recent data available for comparable works taking into account scale of operation where this can be determined.

TABLE VIII/1

LOAN REPAYMENTS

Description	Loan Repayment Period Years	Annual charges at 6½% interest
Impounding Reservoirs - earth dams	60	6.7%
concrete dams	60	6.7%
Concrete structures	40	7.1%
Buildings	30	7.7%
Pipelines 36" and over	40	7.1%
Pipelines under 36"	30	7.7%
Treatment plant	30	7.7%
Pumping machinery	15	10.4%
Reservoirs - reinforced concrete (other than large impounding)	40	7.1%

TABLE VIII/2

UNIT COSTS USED IN PRELIMINARY ANALYSIS

ITEM	Description	Cost Elements		Unit Cost[1] pence/1000 gals.
		Item	Capital Cost	
1	Reservoirs	(a) Earth dams inc. ancillary structures (b) Concrete gravity dams inc. ancillary structures (c) Land, afforestation, road and rail diversions – individual assessment	30/– per c.y. of fill £8 per c.y. Scheduled rates as Table VIII/3	Conservation Cost calculated on total annual charges and estimated net yield to supply
2	River intake works	Weir, intake, coarse screens etc.	£750 per m.g.d.	0.04
3	High lift pumping	(a) Pumping plant including pipework, valves, screens & meters, 50% standby pumping capacity and standby diesel alternators (b) Pump-house (c) Power – including any capital contribution to power supply, and maintenance of machinery	£110 per W.H.P. £2,000 per m.g.d. 1.5d. per k.w.h.	1.0 per 100 ft
4	Pipelines	Bulk transport based on 72" mains carrying 80 m.g.d.	£175,000 per mile	0.10/mile
5	Treatment (a) Single Stage (b) Two Stage – Direct Supply (c) Two Stage – regulated river supplies (d) Softening extra	See Appendix IV		2.5 4.5 5.0 0.3–1.0
6	Terminal storage	Covered reinforced concrete reservoir for 24 hours supply at the notional destination	£25.000 per m.g.	1.2
7	Administration	Maintenance charges on items 1, 2, 4 & 6 and general administration	–	2.0

Note 1: All costs include the costs of investigations, land, legal, engineering, contingencies and interest during construction.

TABLE VIII/3

COSTING RATES USED IN DETAILED COSTING OF PROGRAMMES OF DEVELOPMENT

(including engineering, contingencies and interest during construction)

Item	Description	Unit	Rate
	CAPITAL COSTS		
1.	Earth dams	c.y.	Variable as Diagram VIII/2
2.	Concrete dams	c.y.	Variable as Diagram VIII/3
3.	River intakes	m.g.d.	£750
4.	Pump-houses		
	from:- up to & including 10 m.g.d. capacity	m.g.d.	£3,000
	to:- 60 m.g.d. capacity & above	m.g.d.	£2,000
5.	Pumps and associated equipment		
	including 50% standby pumping capacity and standby diesel alternators	W.H.P.	Variable as Diagram VIII/4
6.	Pipelines (see Tabla VIII/4 and Diagram VIII/6)		
	18"	mile	£24,000
	36"	mile	£60,000
	72"	mile	£168,000
7.	Treatmant works (Diagram VIII/8)		
	Single Stage	m.g.d.	£35,000
	Two Stage	m.g.d.	£50,000
	Softening plant - axtra	m.g.d.	£5,000
8.	Service Reservoirs (Diagram VIII/9)	m.g.	£35,000
	MISCELLANEOUS		
9.	Minor road diversions	lin. y.	£23
10.	Trunk B road diversions	lin. y.	£46
11.	Trunk A road diversions	lin. y.	£92
12.	Land purchase	acre	£50-£250
13.	Compensation for standing timber	acre	£50
14.	Rail diversions single track	lin. y.	£28
	MAINTENANCE CHARGES		
15.	Power for high lift pumping (inc. maintenance of machinery)	K.W.H.	1.5d
16.	Power, labour and chemicals for single stage treatment	1000 g.	1d.
17	Powar, labour and chemicals for two stage treatment	1000 g.	2d.
18	Lime or Lime and Soda softening axtra as App. IV	1000 g.	0.3-1.0d.
19	Administration	1000 g.	2d.

TABLE VIII/4

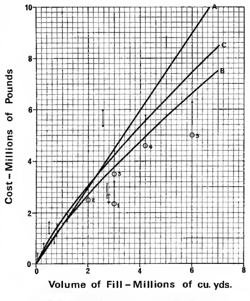
PIPELINES

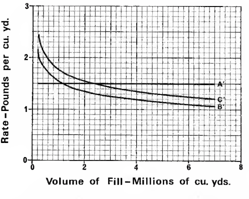
Dia. of Pipe	Assumed cost per mile	Optimum Capacity to nearest half m.g.d.			Head Loss at optimum capacity (100% load factor)	Duplication Quantity	Triplication Quantity
		100% load factor	50% load factor	25% load factor			
Inches	£'000				Ft./mile	m.g.d.	m.g.d.
1	2	3	4	5	6	7	8
24	36	6.5	7.5	9.0	10.7	9.0	16
27	42	8.0	10.0	11.0	9.8	12.0	21
30	48	10.0	12.5	14.0	9.1	15.5	26
33	54	12.5	15.0	17.5	8.6	19.0	32
36	60	15.5	18.5	21.5	8.1	23.0	39
39	69	18.5	22.0	25.5	7.7	27.5	47
42	78	22.0	26.0	30.5	7.3	32.0	56
45	87	26.0	31.0	36.0	7.0	37.5	65
48	96	30.0	36.0	42.0	6.7	43	75
51	105	35.0	41.5	49.0	6.4	49	86
54	114	39.5	47.5	56.5	6.2	56	98
57	123	45	54.0	64.0	6.0	63	110
60	132	50	61.0	72.0	5.8	71	124
63	141	55	68.0	80.5	5.6	80	139
66	150	61	75.5	89.5	5.5	89	154
69	159	68	83.5	98.5	5.4	98	170
72	168	76	92	108.5	5.2	108	187

Notes: *Calculations based on the Hazen Williams formula with an assumed value of $C = 120$.*
Values in Cols. 3 to 8 inclusive have been calculated for diameters of 24", 36", 48", 60" and 72". Values for other diameters have been interpolated from curves drawn for calculated values.

Diag. VIII / 1

COST OF EARTH DAMS





A - N.T.W.P. assumption, December 1966 £1.5/cu yd of fill. Includes ancillary structures, investigations, legal, engineering, contingencies and interest during construction.

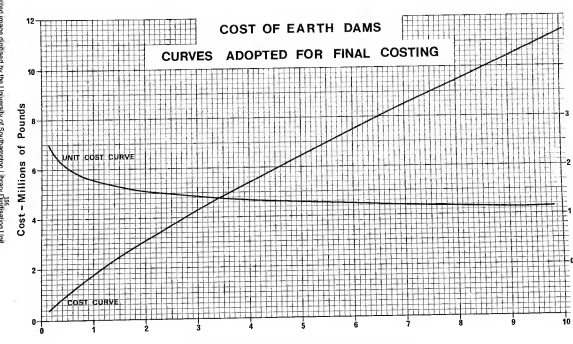
B - W.R.A. T.P.60. Cost of dam (£'000) = 5.7135 ('000 cu yd fill)$^{0.8117}$. Includes only the cost of constructing the dam and engineering works relating directly thereto. Does not include interest or engineering.

C - As B plus 12½% to cover engineering and interest during construction (N.T.W.P. final cost curve, May 1968).

●——●	Span of total reservoir costs; dam construction only at bottom, total at top, from W.R.A.'s own research.
+——+	Ditto for W.R.A.'s research into literature.
⊙——+	Consultants' recent estimates - length of tail is 25% for contingencies etc.

A', B' and C' are unit rate curves corresponding to A, B and C, in left-hand diagram.

Diag. VIII / 2

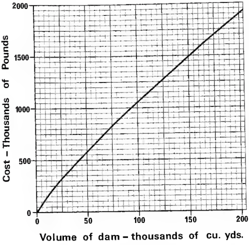


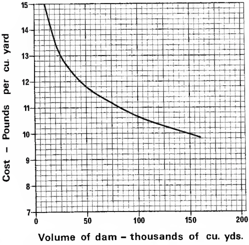
COST OF EARTH DAMS

CURVES ADOPTED FOR FINAL COSTING

The costs indicated include ancillary structures, investigations, legal charges, engineering, contingencies and interest during construction.

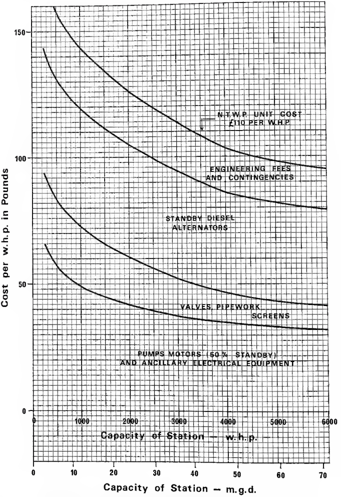
COST OF CONCRETE DAMS



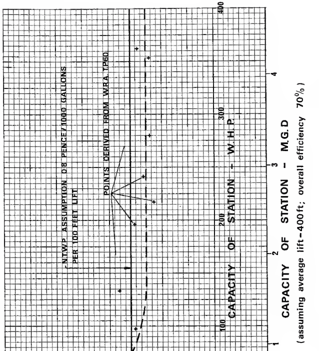


Diag. VIII/4

COST OF PUMPING PLANT AND ANCILLARIES

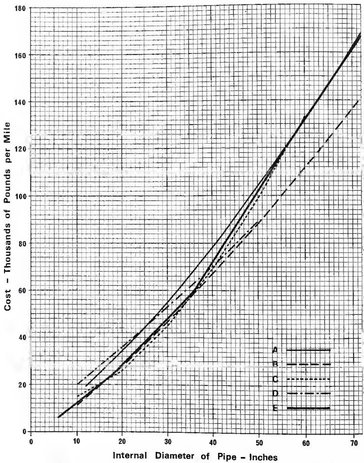


PUMPING STATION ELECTRICITY COSTS



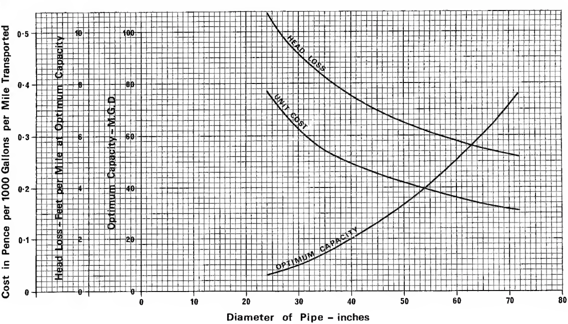
Diag. VIII/6

TOTAL COST OF PIPELINES



A	N.T.W.P. assumption, December 1966. 20/- per inch dia. per yard @ 24 inch dia. to 30/- per inch dia. per yard @ 96 inch dia.
B	W.R.A.T.P.60. Cost (£/yd.) = 0.3487 $(\text{dia. inches})^{1.272}$ (1967 values).
C	C.E.G.B. Planning/DP/34. August 1965. Average cost of pipelines.
D	Binnie's Great Ouse report.
E	N.T.W.P. final cost curve, May 1968

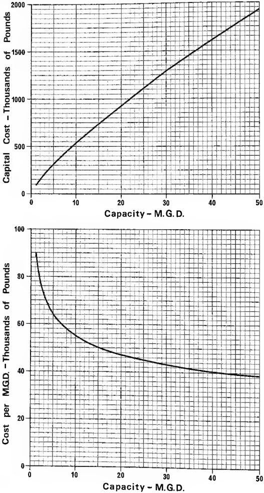
TRANSPORT OF WATER IN PIPELINES



Diag. VIII / 7

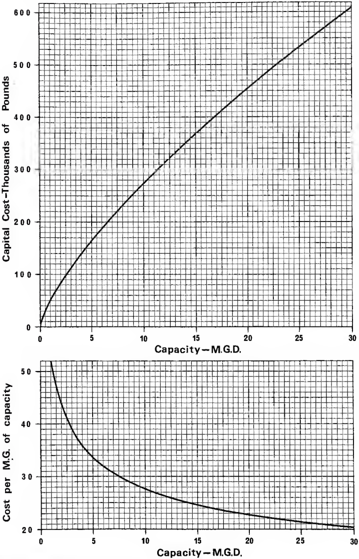
Diag.VIII / 8

COST OF TREATMENT PLANT INCLUDING SEDIMENTATION



COST OF SERVICE RESERVOIRS

Diag. VIII/9



APPENDIX IX.

APPENDIX IX: YIELD ASSESSMENT AND SCHEDULES OF RESOURCES

1. In a regulated system water from storage is used to supplement natural river flows in a dry period so that continuous abstractions to supply can be maintained without depleting the residual flow in the river downstream of the abstraction point below acceptable limits.

2. Within this broad definition regulation systems may be designed to provide, during the regulation period:

either (i) a constant maintained flow reaching the abstraction point with constant abstraction and residual flow;

or (ii) a maintained minimum residual flow and a higher prescribed flow below which the natural flow in the river may not be diminished by abstractions to supply;

or (iii) a maintained minimum residual flow and a higher prescribed flow or flows between which variable abstractions are permitted as a proportion of the naturally occurring flow.

3. For a given yield the maximum demands made upon the storage, by these methods of operation or any permutation of them, depend upon the pattern of dry weather flows occurring in the river during a drought period and upon the abstraction conditions imposed by the river authority. The latter are likely to be determined by the extent of previous developments and the residual flow requirements below the abstraction point, which in turn will depend on the minimum acceptable flow (m.a.f.) determined at this point or elsewhere on the river.

4. For most of the rivers which are considered in this study as potential sources of supply flow data is scanty and abstraction conditions have yet to be determined. Nevertheless if regional programmes of development are to be selected on a rational basis an essential requirement is an objective assessment of the comparative effectiveness of all potential storages when used to regulate river flows. At the same time the assumptions about abstraction conditions should be fairly realistic.

5. As indicated in paragraph 3 the reliable yield of any regulation scheme depends upon:-

(a) Hydrological probability;

(b) Imposed abstraction conditions.

Although these two factors are not wholly independent, in that changes in operating regimes alter the relevance of certain probabilities, they have been considered separately in arriving at yield assessments.

6. With the limited records available the prediction of probable flow sequences in a design drought period involves the selection or processing of data to produce hydrographs, either real or synthetic, for a similar severity of natural conditions. These conditions have been taken to be the sequence of minimum river flows likely to occur, on average, only once in every hundred years. On this basis individual river authorities prepared drought hydrographs for natural conditions in the selected rivers.

7. Since we are primarily concerned with the impact of storage on river flows, the relationship chosen to compare both the severity of design assumptions and the natural characteristics of the river basins was the maintainable flow

storage curve. This shows the river flow that can be maintained or exceeded at the point of abstraction, throughout the design drought, for given releases from storage to augment low river flows.

8. By deducting minimum natural flows to give all curves a common origin, and expressing the increase in maintainable flow and releases from storage in dimensionless terms as percentages of average daily flow (A.D.F.) or average annual flow (A.A.F.) the curves for all the individual rivers could easily be compared. These are shown in Diagram IX/1.

9. For these northern rivers it was found that all curves have a similar characteristic shape and fall reasonably close together. Detailed examination of those which departed furthest above or below the mean suggested that the departures were as likely to be attributable to variations in assumptions made when preparing the drought hydrographs as to any differences between the natural characteristics of the river basins. If design severity had been precisely the same in all cases it is considered that all curves might have fallen within a fairly narrow band.

10. In view of the inadequacy of much of the data upon which the generation of the design hydrographs had been based, it was concluded that fewer errors were likely to be introduced in the evaluation of potential storages by the use of a single maintainable flow/storage curve, than by the use of separate curves whose individuality was suspect. This standard maintainable flow curve is shown as curve B on Diagram IX/2.

11. The proportion of the increase in maintainable flow which may be abstracted as yield to supply is dependent upon the residual flow requirements, as discussed in paragraph 2, and hence upon the licence conditions which may eventually be imposed. Because no such determination has yet been made, nor the relevant licences issued, these proportions are a matter of conjecture.

12. For the rivers concerned tentative assessments were made of the possible requirements for fish, amenities and other interests in an endeavour to derive yield curves from the standard maintainable flow curve. Apart from a general consensus of opinion that in most cases a higher proportion of the increase in maintainable flow should be reserved for river benefit at early stages of development, the resulting yield assessments reflected the diversity of the opinions upon which they were based.

13. If all rivers had similar residual flow requirements it would be logical, following paragraph 9, to define a single yield curve with diminishing proportions of the increase in maintainable flow assigned to river benefit as curve D of Diagram IX/2. However, the requirements of individual rivers will vary, especially in early stages of regulation, casting doubt upon the validity of the early part of the curve if applied as a common basis of assessment for all rivers.

14. Curve D is a net yield curve, providing diminishing yields for equal increments of storage, and implying that there are no existing developments on the river, which again is not true. Some rivers have existing abstractions adequately supported by storage; others have existing licensed abstractions which may be partially or completely unsupported. In the latter case it may be considered necessary, at some time, to provide storage to make good past inroads on the dry weather flow of the river. Providing for these existing conditions and their effects on a yield curve would necessitate a shift in the origin or base line, or both, which in turn would imply commitment to an opinion on all previous abstractions and the storage necessary to support them.

15. Alternatively, if we can assume that a river will ultimately be developed to point A on diagram IX/2 then a straight line from the origin to point A represents the average yield of all the individual schemes making up the ultimate development. This straight line may then be considered as the yield curve for the individual schemes as parts of a sequence of development.

16. The advantages of adopting a straight line are that the increments of yield being equal for equal increments of storage past depredations can be corrected, if necessary, at any point without affecting the yields of preceding or subsequent schemes and yields of individual schemes are not affected by their place in the sequence of development. The disadvantages are, firstly, that the yields of early schemes may be underestimated and of later schemes overestimated, leading to a shortening of the time scale of investment for the total development and, secondly, that theoretically the line should not be extrapolated beyond point A.

17. From the estimates of future deficiencies summarised in Chapter 5 of the Report, this study is concerned with providing additional reliable resources of the order of 1000 m.g.d. over a period of about 30 years, and it is apparent that substantial development of the northern rivers would be necessary if these demands were to be met from rivers regulated by inland storage.

18. For example, if the rivers Lune, Ribble, Dee, Ouse, Derwent and Tyne with a combined A.D.F. of 4500 m.g.d. were developed to meet these demands, effective releases of about 11% of A.A.F. would be required to produce a yield of 23% of A.D.F., equal approximately to 1000 m.g.d. If all northern rivers with a combined A.D.F. of 7500 m.g.d. were developed equally effective releases of about 7% of A.A.F. would be required.

19. In paragraph 56 of Chapter 4 it was suggested that the present economic limit of development of any one of these rivers might be equivalent to effective releases of 16% of A.A.F. Over the range 7% - 16% of A.A.F. the straight line through point A corresponds quite closely to the suggested yield curve D. Thus if ultimate development falls within this range overall errors in yield estimation will be small.

20. For all the foregoing reasons a straight line from the origin through point A terminating at an effective storage of 16% A.A.F. commended itself as the most reasonable basis for assessment of representative yields of regulating schemes on the northern rivers. This linear relationship apparently contradicts the rule of diminishing returns which normally applies to yield storage relationships. It is emphasised that it is essentially a planning device to simplify comparison between alternative schemes and to provide reasonably realistic assessments of the overall yield of a sequence of developments considered as part of a long-term programme.

21. When abstraction conditions are considered for the first regulating scheme on a river system some enhanced early yields may be possible by taking advantage of the proportionately higher increases in flows provided by the first increments of storage. If this should prove to be the case the net result would be the deferment of some subsequent stages of the programme of developments considered in Chapter 7. To this extent our costing of river regulation developments may be slightly pessimistic. It is considered, however, that the linear yield assessment is less likely to lead to errors of selection than attempts to make evaluations of enhanced early yields based upon assumptions about abstraction conditions which cannot be justified by present knowledge.

22. In the case of rivers on which tidal barriers might be constructed at or below the tidal limit different conditions will apply. We are there concerned with the effects of low flows only within the relatively short tidal reaches, rather than over substantial lengths of inland rivers. In appropriate cases lower residual flows should be acceptable, abstraction conditions should be less stringent and greater proportions of the maintainable flow should be available as yield to supply. A tidal barrier yield curve (E Figure IX/4) has been derived from the standard maintainable flow curve on the assumption that the minimum discharge through the tidal barrier is the minimum dry weather flow of the river, and that this should be augmented by an amount rising to 2% of A.D.F. at the limit of development.

23. All maintainable flow and yield curves have been plotted against the effective first-season releases from regulating storage, called the 'effective release'. This is the maximum quantity which it is calculated could be released from storage during a dry summer and which would be effective in maintaining river flow at the abstraction point. Part of the water released would not be effective for this purpose owing to regulation losses - i.e. losses en route and waste resulting from the inability to match releases to subsequent flow conditions at the abstraction point. Moreover, depending on the ease with which the storage can be refilled, either naturally or by pumping, part of the stored water may have to be held over against the needs of a second or even a third dry summer. These factors are determined by the size and location of the storage in relation to the river system.

24. For each potential storage site the refilling cycle has been examined over a three year dry period. The calculations define the maximum first season effective release that the storage and catchment can sustain, as well as making subsequent releases in the second and third years and refilling at the end of the design period. Inflow to storage while regulating water is being released is neglected in these calculations and hence no amendment is required to the design hydrograph at the river abstraction point to allow for the impoundment of run-off from a part of its catchment. A 15% deduction from gross storage has been made to cover regulation losses, dead water and compensation flow which may be required immediately downstream of a reservoir when no regulating releases are required at the abstraction point.

25. In the diagrams IX/7-24 there is first given for each river a curve of maintained flow versus effective releases based upon individual hydrological assessments. The second set of curves for each river are the standard yield curves for inland abstraction points, and tidal barrier curves where appropriate. In the latter case the effect of existing development is taken into account in defining the 'new' net yield curves.

26. In the Schedules II accompanying each set of curves the gross storage is listed at a variety of potential sites and the corresponding effective releases. From the latter the corresponding maintainable flow or yield to supply may be read off the curves.

27. Because the linear yield assessment discounts the effects of the order of developments specific yields can be attributed to every site regulating river flows at an inland abstraction point and these yields are tabulated in the schedules. Where there is a possibility of a tidal barrier being constructed, at or below the tidal limit, the additional increments of yield to supply resulting from the reduction of residual flow requirements are dependent upon the order of development. These additional increments have been tabulated against the first storages in the schedules on the assumption that they will be the first to be developed. If the order of development is changed the tidal barrier increments have to be re-assessed by reading off the yield from the tidal barrier curve against the effective releases of the particular sites.

28. Thus, for example, on the River Leven scheme L2, Winster, the first and cheapest scheme scheduled, with effective releases of 10,200 million gallons would enable a yield of 60 m.g.d. to be drawn from the River Leven at an abstraction point above the tidal limit. If a tidal barrier were then constructed an additional yield of 21 m.g.d. would be made available bringing the total yield of the scheme up to 81 m.g.d. If, for other reasons, the storage at Winster could not be developed then the tidal barrier increment would accrue to the next scheme in the schedule (L3, Killington) making the total yield of that scheme above a tidal barrier 83 m.g.d.

29. Certain large pumped storage reservoirs which could readily be filled from two or more rivers have been notionally divided in the schedules, a portion of the capacity being listed under each river. Furthermore, certain storage sites listed for one river may alternatively be used, without changing the filling arrangements, to balance flows in another within the range of development indicated for the latter. Thus Lancashire scheme L28, Hellifield, which yields 89 m.g.d. on the River Ribble would have a similar yield on the Yorkshire Ouse system (by discharge into the River Wharfe), or the same total yield if divided equally between the two river systems.

30. This result follows automatically from the straight line yield/storage relationship, but in practice spreading a given storage capacity over two or more rivers used in parallel or in series will result in a smaller degree of regulation on each, and will probably give a greater total yield (paragraphs 20 and 21 above). Such compound regulation will deserve consideration, of course, when specific projects are analysed in detail. An example which may offer worthwhile gains is the use of Morecambe Bay storage to balance flows in the Lune, Ribble and the Yorkshire Ouse system as well as the flows of its feeder rivers.

31. In the Morecambe Bay Desk Study the yield from 55,000 million gallons of storage was assessed at 500 m.g.d. This amount of net storage would yield about 340 m.g.d. if spread over the River Leven and River Kent tidal barrier curves (plus a proportionate increase for minor rivers feeding the reservoir) but about 420 m.g.d. if also spread over the River Lune.

32. There may be a case for less stringent residual flow requirements through a barrage across the Bay than near the tidal limits, although for the alternative arrangement of pumped storage lagoons it would be reasonable to apply the 'tidal barrier' yield curves. Bearing this in mind, together with the point noted in paragraph 30 and the possibility of variations in the net volume of storage, we have adopted an intermediate yield figure of 450 m.g.d. and assumed that this will correspond with the average of the cost estimates made in the Desk Study.

33. In certain cases the effect of using existing reservoirs in different ways has been indicated. Substantial economic benefits may often be available from the conjunctive use of existing and new sources e.g. by drawing upon storage in an existing direct supply reservoir or storage developed underground to balance abstractions from other surface sources. In Lancashire schemes L14, 23 and 26 existing storage in Stocks reservoir together with storage developed underground in the Fylde is used in this way to balance abstractions from the Lancashire rivers producing a net gain in yield of 15 m.g.d. On preliminary estimates of costs these schemes appear to offer cheaper supplies for this area than do any other possible developments.

34. Scheme D1 in the Dee & Clwyd Area involves the use of a new reservoir at Brenig, which would greatly over-reservoir its own catchment, in conjunction with existing storage in Bala Lake and Llyn Celyn whose catchments are

comparatively under-reservoired. Such use, in which the existing reservoirs would be drawn down before the new one, would give a yield greater than the schemes would yield independently.

35. Northumbrian schemes 11 and 17 show that converting the existing Derwent Reservoir to regulation (in stages) would be equivalent to finding 5,000 m.g. of new effective releases and would bring a net gain in yield of 29 m.g.d. However, it should not be overlooked that although a net gain of 29 m.g.d. is thus obtained the increased yield of 54 m.g.d. would be obtained near the mouth of the River Wear and the loss of the 25 m.g.d. of direct supply would have to be made good by pumping from there. In this case the necessary duplication of treatment plant and pipelines involved in maintaining the existing supply would appear to impose a heavy cost penalty on the second stage of the conversion. In some of the other cases listed, however - for instance, the Fylde Schemes - the operating economies which could be achieved in average years by always drawing first on the cheapest source in the integrated system may lead to average unit costs somewhat lower than those we have listed. These economies will depend upon the formulation of operating rules for the complete system, taking account of the locations and capacities of aqueducts and treatment works.

36. In preparing the schedules of storages and yields and in drawing up programmes of development no distinction has been made between schemes which regulate the rivers by release of water from storage located in the headwaters, and schemes where storage is used merely to balance abstractions from a river system, and where it may be impracticable to arrange that any significant length of the source river benefits from enhanced flows during the regulation period. In some instances the storage may not even be located in the same river basin, e.g. Killington 'regulating' the River Leven (Lancashire Schedule II River Leven); underground storage in the Fylde balancing abstractions from the River Lune (Lancashire Schedule II River Lune). Nevertheless for all these schemes the same yield/storage rules have been applied, and in balancing schemes (as distinct from true regulation schemes) the proportion of effective storage which is implicitly assigned to improvement of residual river flows may help to offset more rigorous abstraction conditions.

37. Summary Table II contains alternative evaluations of the potential storage sites from Schedules II, when used as direct supply reservoirs. Since the storage is now being used to balance the run-off from its own catchment - usually an upland catchment of comparatively limited area - the gross yields obtainable in this way will generally be less than the corresponding regulated yields from the same storage. Additionally a proportion of the gross yield would have to be deducted for compensation water requirements which have not yet been determined.

38. In certain cases the potential storage exceeds the storage required to balance the run-off in a three-dry-year period and to maintain a constant direct supply. Consideration of refilling periods exceeding three years cannot generally be justified in view of the uncertainty of the basic hydrological data available. Developments have therefore been limited to the three-year balancing storage and are thus comparable with the yield assessments derived for regulated river supplies.

39. In the course of investigations into regulated river supplies generalised curves of minimum accumulated run-off were derived as a function of long average rainfall. Using these curves theoretical storage requirements and gross yields of direct supply reservoirs were calculated in terms of catchment area and long average rainfall. Ineffective storage below lowest draw-off level was taken as 5% of required effective storage and compensation water requirements were assumed to absorb 30% of gross yield, with summer and winter compensation flows in the ratio of 2:1.

40. On these assumptions gross storage/net yield curves were derived as in Diagram IX/6 which also shows for comparison the corresponding net yields calculated for the same gross storage using the Lapworth Chart (Manual of British Water Engineering Practice, 3rd Edition - Chart A Chapter 3). The yield/storage curves denoted by the unbroken line in Diagram IX/6 have been used to evaluate the direct supply yield of all the storages listed in Summary Table II.

41. It must be emphasised that all the yield assessments have been derived to suit the purposes of this essentially comparative exercise. The yields assessed from the curves are only approximate because of the uncertainties about available gross storage pending investigation of sites, the limited hydrological analysis and the inherent approximations in the use of generalised relationships between maintainable flows and available regulating storage.

42. The severity of weather conditions governing the definition of 'reliable yield' is thought to be roughly consistent throughout the lists, but in view of the uncertainties mentioned it would be pointless to relate these yields to a specific annual probability of failure. Moreover, it is considered that in further analysis of a more limited range of schemes this parameter should be expressed in terms of the relationship between yield and the degree of failure to provide that yield continuously. Account should be taken at the same time of the frequency with which demand will match this yield, i.e. of the lower probability of failure, other things being equal, in the course of programmes which are burdened with more redundant capacity.

POTENTIAL RESOURCES

SCHEDULE I - ISOLATED SOURCES

Scheme No.	Description and Site	Possible Yield (m.g.d.)	Basis of Computation	Cost/1000 gals. (pence) Treated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
1	Minor river regulation River Font/Wansbeck Stanton (modified)	4	River flow records		x			
2	Underground sources Magnesian Limestone	10	Estimated infiltration		x		Tees Valley and Cleveland Water Board Hartlepools Water Company	Test drilling in hand.
3	Underground sources Triassic Sandstone	5	Estimated infiltration		x		"	
4	Abstraction from the River Tyne.	9	River flow records		x		Newcastle and Gateshead Water Co.	Yield will be reduced in the event of a reservoir being built to regulate the Tyne.

Total Potential	*28*
Probable development	*19*

POTENTIAL RESOURCES

SCHEDULE 1 - ISOLATED SOURCES

Scheme No.	Description and Site	Possible Yield m.g.d.	Basis of Computation	Cost/1000 gals. (pence) Treated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
	North and East Yorkshire							
1	Etton No. 2 and 3 boreholes	1.0	Hydro/ Geological appraisal	x			E. Yorks. (W.A.) W.B.	No powers.
2	Grindale borehole	2.5		x			"	"
3	Further ground-water abstraction	2.0		x			"	"
4	Clifton – R. Intake on R. Ure	2.0	Analysis of river flow records		x		Northallerton and The Dales W.B.	Licence granted but no powers.
5	Fossdale Springs	0.1	Gauging of spring flow	x			"	Investigation held.
6	Keld Head, Pickering Impounded spring	0.7	"		x		Ryedale Joint W.B.	Increased Yield of existing source.
7	7 boreholes in Sandstone, Limestone and Chalk	5.5	Consideration of geological conditions at site		x		"	No powers – subject to geological appraisal.
8	Boreholes in Vale of Pickering	5.0	"			x	Scarborough Corp. Water Department	"
		18.8						

POTENTIAL RESOURCES

SCHEDULE I - ISOLATED SOURCES

Scheme No.	Description and Site	Possible Yield m.g.d.	Basis of Computation	Cost/1000 gals. (pence,) Treated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
	South West Yorkshire & Humberside							
	c.f.	18.8						
9	Rake Dike – catchwater	0.5	Analysis of rainfall and run-off			x	Mid-Calder W.B.	Existing powers.
10	Newsholme Dene – reservoir	2.1	Analysis of rainfall and run-off and reservoir capacity			x	Craven W.B.	No powers.
11	Boreholes in various locations	1.1	Consideration of geological conditions at sites		x		"	No powers.
12	Overwood – Direct Supply Reservoir	7.1	Analysis of rainfall, run-off and reservoir capacity			x	Calderdale W.B.	No powers but scheme being actively promoted.
13	R. Hull supplemented by boreholes	10	Hydrogeological assessment			x	Hull & Humberside	
14	Various existing impounding schemes	2	Re-assessment of compensation water	x			Various water authorities	Yield is a conservative estimate.

Total Potential	*41.6*
Probable Development	*25*

POTENTIAL RESOURCES

SCHEDULE I - ISOLATED SOURCES

Scheme No.	Description and Site	Possible Yield m.g.d.	Basis of Computation	Cost/1000 gals. (pence) Treated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
1	Boreholes at Kinnerton	1.0	Assessment of aquifer yield		x		Central Flintshire Water Board	New Source.
2	Increased abstraction from the River Aled at Bryn Aled	1.0	Analysis of River flows		x		West Denbighshire & West Flintshire Water Board	

Total potention 2

Probable development 2

POTENTIAL. RESOURCES

SCHEDULE I - ISOLATED SOURCES

Scheme No.	Description and Site	Possible Yield m.g.d.	Basis of Computation	Cost/1000 galls. (pence) Treated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
1	R. Weaver – Nantwich – direct abstraction integrated with boreholes in Delamere	5	Analysis of river flows		x		Mid Cheshire W.B.	Requires boreholes capable of 8 m.g.d. yielding 3 m.g.d. over year.
2	R. Weaver – Winsford – regulation of Flash	4	Analysis of river flows		x		Mid Cheshire W.B. Industrial	Multipurpose scheme – flood control and industrial water. Amenity aspects probably favourable (boating etc.) but geology will possibly cause difficulties.
3A	R. Dane – Hugbridge – direct abstraction integrated with boreholes near Prestbury	(5)	Analysis of river flows		x		Macclesfield and Stockport	Requires boreholes capable of 9 m.g.d. yielding 4 m.g.d. over year. See also 18.
OR 3B	R. Dane – Impounding reservoir above Hugbridge	10	Rainfall data		x		Macclesfield and Stockport	Possibility of impounding requires investigation into dam sites, which are likely to be within National Park.
4	R. Gowy – Hergrave – direct abstraction and additional boreholes in Bunter Sandstone nearby	3	Analysis of river flows		x		Ellesmere Port area Industrial	Integrated Scheme. Ellesmere Port area requires boreholes capable of 4 m.g.d. yielding 2 m.g.d. over year.
	c.f.	22						

Scheme No.	Description and Site	Possible Yield m.g.d.	Basis of Computation	Cost/1000 galls. (pence) Treated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
	b.f.	22						
5	R. Irwell – Stubbins – pumped storage	6	Prescribed flow 15 m.g.d. A.D.F. 64 m.g.d.		x		Bolton	Yield dependent on location of suitable storage site (Musbury Valley SD.770213 or Upper Bradshaw Valley SD.732188). Investigations into river flows and quality required.
6	Conversion of compensation to prescribed flow – Rivers Irwell and Croal	2+		x			Bolton	See NOTE (1).
7	Conversion of compensation to prescribed flow – River Roch	1.5+		x			Rochdale	See NOTE (1).
8	Longden End – intake	0.5	Rainfall and Run-Off	x			Oldham	
9	Dean Brook – abstraction into High Rid Reservoir	0.6	Calc. run-off less D.W.F. less 10%	x			Oldham	
10	Shelf Brook – impounding	4	By comparison with Longdendale			x	South Lancashire	Reservoir site in National Park.
	c.f.	36.6						

(1) Dependent upon (a) Investigations into present flows and development of control systems.

(b) Agreement with Statutory Undertakers and other abstractors downstream.

(c) Formal variation of Licences.

Scheme No.	Description and Site	Possible Yield m.g.d.	Basis of Computation	Cost/1000 galls. (pence) Treated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
	b.f.	36.6						
11	Conversion of compensation to prescribed flow – Longdendale	1.5+	Simulation technique based on run-off records.	x			Manchester	See NOTE (1).
12	R. Tame – Slackcote – impounding reservoir with prescribed flow station at Uppermill	2	Rainfall		x		Oldham	Investigations into river flows required. May be possible to increase yield by pumping from Uppermill (SD.995051).
13A	Glaze Brook – direct abstraction	(1)	Analysis of river flows		x		Makerfield	Quality doubtful but improving.
OR 13B	Glaze Brook – direct abstraction linked with boreholes south of Leigh	3			x		Makerfield	See NOTE (1).
14A	R. Bollin – direct abstraction	(5)	Analysis of river flows		x		Warrington	
OR 14B	R. Bollin – direct abstraction linked with boreholes north and south of Warrington	10			x		Warrington	Requires boreholes capable of 14 m.g.d. yielding 4 m.g.d. over year. See NOTE (1).
15	R. Mersey – direct abstraction – non potable	7+		x			Warrington	
16	Rainford Brook – intake	1			x		St. Helens	Flow and quality doubtful.
	c.f.	61.1						

(1) Dependent upon (a) Investigations into present flows and development of control systems.

(b) Agreement with Statutory Undertakers and other abstractors downstream.

(c) Formal variation of Licences.

Scheme No.	Description and Site	Possible Yield m.g.d.	Basis of Computation	Cost/1000 galls. (pence) Treated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
	b.f.	61.1						
17	Gritstone boreholes – Oldham/Rochdale Area	2+	Pumping records and Consultants Reports	x			Oldham and Rochdale	Larger Yields might be obtainable but a large number of boreholes would be needed. The aquifer might usefully be developed as a replacement for compensation water from existing reservoirs.
18	Bunter Sandstone – north of Macclesfield	10			x		Macclesfield W.B.	This area is still comparatively undeveloped. Final yield dependent on results of investigations. See also 3A.
19	Bunter Sandstone – northwest and west Cheshire	8.5			x		Staff. Potteries Warrington Mid-Cheshire	This area is being actively developed by Warrington, Mid Cheshire and Staff. Potts. and present proposals appear likely to reach the present safe limit for abstractions. See also 1 and 148.

Total Potential *81.8*

Probable Development *60*

POTENTIAL RESOURCES

SCHEDULE I - ISOLATED SOURCES

Scheme No.	Description and Site	Possible Yield m.g.d.	Basis of Computation	Cost/1000 gals. (pence) Untreated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
1	River Duddon	4.0		x			Furness Water Board	Quantity dependent on m.a.f. requirements and location of suitable storage facilities.
2	Levers Water	0.5		x			Furness Water Board	
3	Borrans, Windermere	0.5		x			Lakes & Lune Water Board	Subject to alteration in compensation water provisions.
4	Mintsfeet, Kendal	1.0			x		-do-	
5	Wyresdale Fells	3.0		x			Lune Valley Water Board	
6	Caton Moor	0.3		x			-do-	
7	Swarth Beck, Carnforth	0.5		x			-do-	
8	Waddington Fell, Clitheroe	0.5		x			Fylde Water Board	
9	Wycoller Reservoir	1.75				x	North Calder Water Board	
10	Boreholes Unspecified	0.5		x			-do-	
11	Sharn Hall	1.9			x		Calder Water Board	
12	Hapton Valley-Minewater	0.75			x		-do-	
13	Fir Trees-Minewater	0.5			x		-do-	
14	Langden & Hareden Intakes	1.6	Records of run-off	x			Preston & District Water Board	Additional yield following provision of full treatment facilities.
	Total Potential	*17.3*						
	Probable Development	*10*						

POTENTIAL RESOURCES

SCHEDULE I - ISOLATED SOURCES

Scheme No.	Description and Site	Possible Yield m.g.d.	Basis of Computation	Cost/1000 gals. (pence) Treated at Service Reservoir			Distribution Area	Remarks
				Under 12	12 to 24	Over 24		
1	River Eden, Wetherall Additional abstraction	4	Flow records	x			Carlisle C.B.C.	
2	Chapel House – Overwater	4	Lapworth Report	x			W. Cumb. W.B.	In National Park.
3	Hardknott, River Esk	21	Hydrological Survey		x		Furness W.B.	In National Park.
4	Burnmoor Tarn	6	Lapworth Report		x		Furness W.B.	In National Park.
5	Ground Water, S.W. Cumb.	6			x		S. Cumb. W.B.	Exploratory work to be undertaken soon. Test drilling may reveal a higher possible yield in conjunction with surface sources.
6	Ennerdale – raising of lake levels	9		x				
7	Additional boreholes Eden Valley	1	Geological appraisal	x			Eden Valley W.B.	To meet increase in demand to 2001.

Total Potential	*51*
Possible Development	*14*

A.D.F. assumed at Guyzance: 195 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						REMARKS
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield m.g.d.	Conservation Cost d/1000g	Increment of Yield m.g.d.	Conservation Cost d/1000g	Yield m.g.d.	Conservation Cost d/1000g	
		m.g.	ft. A.O.D.	Sq. Miles	Ins.	m.g.							
N1	Barrow Burn[3]	3,400	640	9.1	41	2,400	14	3.2	-	-	14	3.2	
N2	River Coquet[3]	6,300	900	23.1	45	5,350	31	3.4	-	-	31	3.4	
N3	River Alwin[3]	3,500	785	10.2	43	2,500	15	5.9	-	-	15	5.9	

Notes:- *1. After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. See paras. 20-27 of Appendix IX.
3. Within National Park.

RIVER TYNE

NORTHUMBRIAN RIVER AUTHORITY

A.D.F. assumed at Bywell: 800 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage m.g.	T.W.L. ft. A.O.D.	Catchment Area sq. miles	Long Average Rainfall ins.	Effective First Season Releases[1] m.g.	YIELDS AND CONSERVATION COSTS[2] STRAIGHT LINE Yield m.g.d.		TIDAL BARRIER Increment of Yield m.g.d.		TOTAL COMBINED Yield m.g.d.		REMARKS
								STRAIGHT LINE Conservation Cost d/1000g		TIDAL BARRIER Conservation Cost d/1000g		TOTAL COMBINED Conservation Cost d/1000g	
N4	Irthing[3]	15,800	725	37.8	46	12,600	73	1.3	–	–	73	1.3	On R. Irthing.
N5	Otterstone[3]	48,000	610	96.0	48	36,000	210	1.8	–	–	210	1.8	
N5A	Otterstone	48,000	613	96.0	48	36,000	210	2.9	–	–	210	2.9	)Alternative site)outside N.P.
N6	Saffronside[3]	4,400	690	36.9	44	3,750	22	3.6	–	–	22	3.6	
N7	Chirdon Burn[3]	3,600	570	17.8	40	3,050	18	3.6	–	–	18	3.6	
N8	Holt[3]	8,500	570	74.6	40	7,200	42	4.0	–	–	42	4.0	
N9	Warks Burn[3]	1,630	695	15.0	38	1,400	8	5.0	–	–	8	5.0	
N10	Tarset Burn	2,700	640	23.8	38	2,300	13	7.1	–	–	13	7.1	

Notes:-
1. *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*
3. *Within National Park.*

RIVER WEAR

A.D.F. assumed at Croxdale: 210 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						Remarks
							STRAIGHT LINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield	Conservation Cost	Increment of Yield	Conservation Cost	Yield	Conservation Cost	
		m.g.	ft. A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g	m.g.d.	d/1000g	m.g.d.	d/1000g	
N11	Existing Derwent Stage I	2,600	–	–	–	1,900	11	2.9	–	–	11	2.9	Use of part of storage in Derwent reservoir.
N12	Witton-le-Wear	19,400	425	163.0	30	15,700	91	3.4	–	–	91	3.4	
N13	Browney Stage I	2,500	515	15.5	31	2,120	12	5.5	–	–	12	5.5	Yield and costs for Stage I only.
N14	Bedburn	4,500	635	21.0	38	3,800	22	7.0	–	–	22	7.0	
N15	Browney Stage II	8,000	575	15.5	31	6,800	40	10.1	–	–	40	10.1	Yield and costs for second increment of development. Pumped storage scheme.
N16	Middlehope	1,900	1,275	3.6	52	1,600	9	13.0	–	–	9	13.0	
N17	Existing Derwent Stage II	8,400	–	–	–	3,100	18	15.4	–	–	18	15.4	Conversion of the remaining Derwent storage to regulation net gain after stage I, 18 m.g.d.

Notes:- 1. *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*

A.D.F. assumed at Low Worsall: 352 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage m.g.	T.W.L. ft. A.O.D.	Catchment Area sq. miles	Long Average Rainfall ins.	Effective[1] First Season Releases m.g.	YIELDS AND CONSERVATION COSTS[2]						REMARKS
							STRAIGHT LINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield m.g.d.	Conservation Cost d/1000g	Increment of Yield m.g.d.	Conservation Cost d/1000g	Yield m.g.d.	Conservation Cost d/1000g	
N18	Middleton	20,000	898	90.0	52	17,000	80	6.7	–	–	80	6.7	
N19	Egglestone Burn Stage I	2,500	1,135	8.8	44	2,100	10	7.4	–	–	10	7.4	
N20	Upper Grete	1,400	850	18.8	42	1,200	6	7.7	–	–	6	7.7	
N21	Upper Maize Beck	4,600	1,770	11.9	70	3,900	18	8.3	–	–	18	8.3	
N22	Egglestone Burn Stage II	5,800	1,200	8.8	44	5,000	23	13.0	–	–	23	13.0	Yields and costs for second increment of development.
N23	Hudeshope	1,300	1,000	6.5	49	1,100	5	16.1	–	–	5	16.1	
N24	Sleightholme	1,100	1,200	10.6	49	935	4	16.5	–	–	4	16.5	

Notes:- 1. *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*

RIVER OUSE (including Nidd)

YORKSHIRE OUSE AND HULL RIVER AUTHORITY

A.D.F. assumed at Nun Monkton: 1100 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						REMARKS
							STRAIGHT LINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield	Conservation Cost	Increment of Yield	Conservation Cost	Yield	Conservation Cost	
		m.g.	ft. A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g	m.g.d.	d/1000g	m.g.d.	d/1000g	
Y1	Existing Gouthwaite	1,560	446	19.6	46	1,320	8	0.2	–	–	8	0.2	Change of use of existing reservoir.
Y2	New Gouthwaite	6,500	484	19.7	46	5,500	24	3.0	–	–	24	3.0	New dam d/s of existing dam. Floods Ramsgill.
Y3	Bishopdale stage I[3]	9,100	647	20.0	55	7,800	45	4.1	–	–	45	4.1	
Y4	Arkle Beck[3]	8,850	895	2.5	48	7,500	44	4.4	–	–	44	4.4	Floods Langthwaite
Y5	Birkby Nab	6,400	297	26.0	38	5,100	30	4.9	–	–	30	4.9	Good quality land 2A and 4E classification.
Y6	Bishopdale stage II[3]	14,000	716	47.4	60	11,800	69	6.8	–	–	69	6.8	Yields and costs for second increment of development.
Y7	Snaizeholme stage I[3]	5,620	1,061	8.8	72	4,800	28	8.9	–	–	28	8.9	
Y8	Kisdon[3]	6,900	1,000	33.0	65	5,850	34	13.2	–	–	34	13.2	
Y9	Snaizeholme stage II[3]	5,280	1,112	18.5	69	4,500	26	15.2	–	–	26	15.2	Yields and costs for second increment of development.
Y10	Marston Moor	1,650	80	–	–	1,500	9	20.0	–	–	9	20.0	Pumped storage.

Notes:- 1. *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*
3. *Within National Park.*

RIVER WHARFE

A.D.F. assumed at Flint Mill: 305 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage m.g.	T.W.L. ft. A.O.D.	Catchment Area sq. miles	Long Average Rainfall ins.	Effective[1] First Season Releases m.g.	YIELDS AND CONSERVATION COSTS[2]						REMARKS
							STRAIGHT LINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield m.g.d.	Conservation Cost d/1000g	Increment of Yield m.g.d.	Conservation Cost d/1000g	Yield m.g.d.	Conservation Cost d/1000g	
Y11	Existing Washburn Valley reservoirs and Eccup:– Thruscross, Fewston, Swinsty, Lindley Wood, Eccup	3,437 670 1,410				1,050	6	0.4			6	0.4	Direct supply system supplemented by river abstractions.
Y12	Grimwith[3]	4,300	942	9.8	53	3,650	21	4.5			21	4.5	Enlargement of existing reservoir.

Notes:- *1.* *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*
3. *Within National Park.*

RIVER DERWENT

A.D.F. assumed at Stamford Bridge: 273 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						REMARKS
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield	Conservation Cost	Increment of Yield	Conservation Cost	Yield	Conservation Cost	
		m.g.	ft. A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g.	m.g.d.	d/1000g.	m.g.d.	d/1000g.	
Y13	Farndale[3]	5,900	550	24.1	41	4,350	25	11.5					
	Tidal sluices at Derwent mouth								22	0.2	47	6.2	
						COST OF TIDAL BARRIER ESTIMATED AT £0.1M.							

Notes:-
1. After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.
2. See paras. 20-27 of Appendix IX.
3. Within National Park.

RIVER CLWYD

A.D.F. assumed at Pont-y-Cambwll:
126 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						REMARKS
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield	Conserv-ation Cost	Increment of Yield	Conserv-ation Cost	Yield	Conserv-ation Cost	
		m.g.	ft. A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g.	m.g.d.	d/1000g.	m.g.d.	d/1000g.	
D1	Brenig (large, part) principally regulating the Dee but also regulating the Clwyd.	2,200	1,250	7.8	51.5	1,730	10	5.0	–	–	10	5.0	
D2	Regulation of R. Clwyd by underground water from tube wells upstream of Bodfari.	–	–	–	–	500	3	5.6	–	–	3	5.6	Abstractions possibly at Bodfari and St. Asaph.
D3	Regulation of R.Clwyd by Upper Clwyd Reservoir.	2,340	725	6.6	43	1,730	10	13.9	–	–	10	13.9	

Notes:- 1. *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*

RIVER DEE

A.D.F. assumed at Chester: 740 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II- REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						REMARKS
							STRAIGHT LINE		TIDAL BARRIER		TOTAL COMBINED		
		m.g.	ft. A.O.D.	sq. miles	ins.	m.g.	Yield m.g.d.	Conservation Cost d/1000g.	Increment of Yield m.g.d.	Conservation Cost d/1000g.	Yield m.g.d.	Conservation Cost d/1000g.	
D4	Existing Llyn Celyn^3	–	–	–	–	1,050	6	0.1	–	–	6	0.1	Increase in yield due to excess of storage over design storage.
D5	Improvement in regulating efficiency of R. Dee	–	–	–	–	1,200	7	0.1	–	–	7	0.1	W.R.B. Research Programme.
D1	Brenig (large. part) principally regulating the Dee but also regulating the Clwyd	16,300	1,250	7.8	51.5	12,070	70	3.0	–	–	70	3.0	Operated in conjunction with Bala and Llyn Celyn which have surpluses in 2nd and subsequent dry years.
D6	Twrch^3	4,850	1,130	3.8	80.0	3,500	20	5.9	–	–	20	5.9	
D7	Hirnant^3	8,800	1,000	10.7	68.0	7,000	40	7.6	–	–	40	7.6	Storage available on Hirnant site up to 11,000 m.g.
D8	Existing Alwen	2,600	–	–	–	700	4	8.3	–	–	4	8.3	Existing 8.2 m.g.d. direct supply yield maintained and treated.

Notes:- 1. *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*
3. *Within National Park.*
Existing regulated yield from the R. Dee is 117 m.g.d.

A.D.F. assumed at Duddon Viaduct: 114 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2] STRAIGHTLINE Yield	STRAIGHTLINE Conservation Cost	TIDAL BARRIER Increment of Yield	TIDAL BARRIER Conservation Cost	TOTAL COMBINED Yield	TOTAL COMBINED Conservation Cost	REMARKS
		m.g.	ft. A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g.	m.g.d.	d/1000g.	m.g.d.	d/1000g.	
L1	Duddon[3]	6,500	173	33.4	84	5.600	32	3.0	10	6.4	42	3.8	Scheme selected as representative of possible developments in the Duddon Valley with yields ranging from 10 to 50 m.g.d. The reservoir would submerge the existing intake works at Ulpha.
					COST OF TIDAL BARRIER ESTIMATED AT £1.35M.								

Notes:-

1. *After consideration of dead water in the reservoir. compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*
3. *Within National Park and unacceptable to Amenity & Planning Sub-Committee of Jellicoe Conference (HMSO 1963)*

RIVER LEVEN

A.D.F. assumed at Greenodd: 388 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						REMARKS
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield	Conservation Cost	Increment of Yield	Conservation Cost	Yield	Conservation Cost	
		m.g.	ft. A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g.	m.g.d.	d/1000g.	m.g.d.	d/1000g.	
L2	Winster[3]	12,000	100	–	–	10,200	60	3.8	21	2.2	81	3.4	Pumped Storage.
L3	Killington (Part only) See R. Kent schedule for remainder	13,200	675	–	–	10,600	62	9.1	–	–	62	9.1	Pumped Storage. Smaller scheme of 15,000 m.g. gross storage more economical.

COST OF TIDAL BARRIER ESTIMATED AT £1.0M.

Notes:-

[1] After consideration of dead water in the reservoir, compensation flow and refilling conditions.

[2] See paras. 20-27 of Appendix IX

[3] Within National Park. The subject of statements by Minister of Housing and Local Government in 1966

A.D.F. assumed at Arnside Viaduct: 320 m.g.d. POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage m.g.	T.W.L. ft.A.O.D.	Catchment Area sq. miles	Long Average Rainfall ins.	Effective First Season Releases[1] m.g.	YIELDS AND CONSERVATION COSTS 2						Remarks
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield m.g.d.	Conservation Cost d/1000g	Increment of Yield m.g.d.	Conservation Cost d/1000g	Yield m.g.d.	Conservation Cost d/1000g	
L4	Sprint Lower[3]	11,400	619	10.2	96	9,200	53	1.4	30	3.9	83	2.3	Would flood Longsleddale which was subject of strong opposition in Manchester Inquiry proceedings in 1965.
L5	Mint (Meal Bank)	4,000	411	22.2	74	3,400	20	3.3	–	–	20	3.3	
L6	Kent (Lower)[3]	6.500	597	12.5	88	5,500	32	3.6	–	–	32	3.6	
L7	Peasey Beck	6,100	394	11.0	58	5,200	30	3.8	–	–	30	3.8	
L8	Lupton Beck	3,850	323	10.1	55	3,250	19	3.9	–	–	19	3.9	
L9	Bannisdale Lower[3,4]	2,500	552	7.4	86	2,100	12	7.4	–	–	12	7.4	
L3	Killington (Part only)	14,900[5]	675	–	–	12,000	70	9.1[6]	–	–	70	9.1	Pumped Storage See R. Leven remarks.
L10	Arnside High Level[3] Impoundment	18,000	75	–	–	15,300	89	12.0	–	–	89	12.0	Pumped Storage.
						COST OF TIDAL BARRIER ESTIMATED AT £2.5M.							

Notes:-
1. *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*
3. *Within National Park.*
4. *Unacceptable to Amenity & Planning Sub-Committee of Jellicoe Conference (HMSO 1963)*
5. *Gross storage 28,100; balance appears in R. Leven schedule.*
6. *Refilled from Lune and Kent.*

RIVER LUNE

A.D.F. assumed at Halton: 655 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage m.g.	T.W.L. ft.A.O.D.	Catchment Area sq. miles	Long Average Rainfall ins.	Effective[1] First Season Releases m.g.	YIELDS AND CONSERVATION COSTS[2] STRAIGHTLINE Yield m.g.d.		TIDAL BARRIER Increment of Yield m.g.d.		TOTAL COMBINED Yield m.g.d.		Remarks
							Yield m.g.d.	Conservation Cost d/1000g	Increment of Yield m.g.d.	Conservation Cost d/1000g	Yield m.g.d.	Conservation Cost d/1000g	
L11	Roeburn[3]	3,050	935	3.6	71	2,300	13	1.1	15	1.7	28	1.4	Could alternatively be used for regulating the R. Ribble.
L12	Dee[4]	9,700	448	28.1	72	7,900	46	1.4	30	1.7	76	1.5	Would drown the village of Dent.
L13	Roeburn (Mallowdale)[3]	880	750	4.3	65	750	4	1.9	1	1.7	5	1.8	See remarks applicable to Scheme L11.
L14	Existing Stocks and Underground Storage	–	–	–	–	860	5	2.5	1	1.7	6	2.4	Boreholes in Garstang area.
L15	Flake Bridge[5]	7,250	790	10.7	67	4,800	28	4.2	8	1.7	36	3.5	
L16	Birk Beck	1,950	645	16.0	74	1,600	9	5.6	–	–	9	5.6	
L17	Greta[4]	9,250	815	13.0	70	6,100	36	4.7	–	–	36	4.7	
L18	Hindburn (Upper)[3]	3,000	418	16.1	63	2,500	15	5.8	–	–	15	5.8	See remarks applicable to Scheme L11.
L19	Borrow Beck[5]	16,000	844	10.2	88	13,700	80	7.0	–	–	80	7.0	Concrete Dam. Partially pumped storage.
L20	Barbon Beck	2,900	637	6.6	70	2,340	14	7.1	–	–	14	7.1	
L21	Langdale	1,400	898	5.1	82	1,220	7	8.8	–	–	7	8.8	
L22	Bowderdale	1,400	1,020	2.6	79	1,000	6	14.3	–	–	6	14.3	
							COST OF TIDAL BARRIER ESTIMATED AT £2.0M.						

Notes:-
1. *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*
3. *Within Area of Outstanding Natural Beauty.*
4. *Within National Park.*
5. *Acceptable to Amenity & Planning Sub-Committee of Jellicoe Conference (HMSO 1963).*

A.D.F. assumed at St. Michaels: 125 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						Remarks
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield	Conservation Cost	Increment of Yield	Conservation Cost	Yield	Conservation Cost	
		m.g.	ft.A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g	m.g.d.	d/1000g	m.g.d.	d/1000g	
L23	Existing Stocks and Underground Storage	–	–	–	–	860	5	2.5	–	–	5	2.5	Boreholes in Garstang area.
L24	Wyre (Upper)[3]	4,000	400	23.6	63	3.400	20	4.1	–	–	20	4.1	

Notes:- *1. After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. See paras. 20-27 of Appendix IX.
3. Within Area of Outstanding Natural Beauty.

A.D.F. assumed at Hodder Foot: 406 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						Remarks
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
		m.g.	ft.A.D.	sq.miles	ins.	m.g.	Yield m.g.d.	Conservation Cost d/1000g	Increment of Yield m.g.d.	Conservation Cost d/1000g	Yield m.g.d.	Conservation Cost d/1000g	
L25	Existing Longridge	–	–	–	–	340	2	2.2	–	–	2	2.2	Preston and District Water Board's existing reservoirs.
L26	Existing Stocks and Underground Storage	–	–	–	–	860	5	2.5	–	–	5	2.5	Boreholes in Broughton area.
L27	Stock Beck	800	401	12.5	45	680	4	2.6	–	–	4	2.6	
L28	Hellifield [3] Horton [4]	18,000 4,000	445 744	78.5 34.1	61) 72)	15,300	89	3.0	–	–	89	3.0	L28 Hellifield can be developed in a number of ways, to the T.W.L. of 445 or to a lower T.W.L. with additional storage at Horton. The cost quoted is representative of the various possibilities.
L29	Hodder Upper[5]	16.000	424	68.5	64	12.100	70	3.1	–	–	70	3.1	
L30	Stankhill Beck	1,650	435	4.7	45	1.120	7	3.7	–	–	7	3.7	
L31	Ex. Rivington[5]	–	–	–	–	1,030	9	5.9	–	–	9	5.9	Liverpool Corporation Water Works existing reservoirs.
L32	Croasdale[5,6]	1,500	625	4.5	72	1,350	8	8.0	–	–	8	8.0	L28 & L29 Costs include an allowance for dredging at Preston Docks which may be necessary due to variations in river flow resulting from these major impoundments.
L33	Dunsop[5,6]	4,000	614	10.5	72	3,300	19	9.3	–	–	19	9.3	
L34	Langden[5,6]	4,500	675	10.2	69	3,800	22	9.6	–	–	22	9.6	
L35	Skirdon Beck[5]	2.750	460	10.6	49	2,100	12	10.9	–	–	12	10.9	

Notes:-
1. *After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. *See paras. 20-27 of Appendix IX.*
3. *Acceptable to Amenity & Planning Sub-Committee of Jellicoe Conference (HMSO 1963).*
4. *Practicability depends upon railway line being abandoned completely.*
5. *Within Area of Outstanding Natural Beauty.*
6. *Unacceptable to Amenity & Planning Sub-Committee of Jellicoe Conference (HMSO 1963).*

RIVER DERWENT

A.D.F. assumed at Workington: 514 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						Remarks
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield	Conservation Cost	Increment of Yield	Conservation Cost	Yield	Conservation Cost	
		m.g.	ft.A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g	m.g.d.	d/1000g	m.g.d.	d/1000g	
C1	Cocker[3]	18,000	275	48	77	15,300	89	1.6	42	1.1	131	1.4	
C2	Marron	14,000	415	11	55	10,300	60	4.6	–	–	60	4.6	
C3	Newlands Beck[3]	3,600	350	9.8	95	3,060	18	5.1	–	–	18	5.1	
C4	Carr Beck	2,000	230	2.7	42	1,700	10	5.3	–	–	10	5.3	
C5	Lostrigg Beck	4,000	280	5	45	2,800	16	5.8	–	–	16	5.8	
C6	Thirlmere[3]	8,900	590	15.8	106	7,600	44	–	–	–	–	–	Yield on tidal barrier would be 77 m.g.d. Existing yield 56 m.g.d. Conservation cost would be dependent upon cost of replacement source.
					COST OF TIDAL BARRIER ESTIMATED AT £1.0M.								

Notes:- *1. After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. See paras. 20-27 of Appendix IX.
3. Within National Park.

The yields of new schemes have been assessed on the assumption that Bassenthwaite control is constructed to improve minimum flows under present abstraction conditions.

RIVER: CALDER, BLENG & IRT

A.D.F. assumed; 140 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						Remarks
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield	Conservation Cost	Increment of Yield	Conservation Cost	Yield	Conservation Cost	
		m.g.	ft.A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g	m.g.d.	d/1000g	m.g.d.	d/1000g	
C7	Wastwater[3]	1,200	203	17.2	115	1,040	6	1.3	–	–	6	1.3	
C8	Mosedale Beck[3]	1,300	500	2.4	144	1,100	6	6.7	–	–	6	6.7	
C9	Bleng[3]	2,750	915	3.0	90	2,340	14	7.8	–	–	14	7.8	
C10	Calder[3]	2,500	525	–	–	2,120	12	8.7	–	–	12	8.7	

Notes:- *1. After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. See paras. 20-27 of Appendix IX.
3. Within National Park.

A.D.F. assumed at Carlisle: 980 m.g.d.

POTENTIAL RESOURCES

SCHEDULE II - REGULATED RIVERS

Scheme No.	Description and Site	Gross Storage	T.W.L.	Catchment Area	Long Average Rainfall	Effective[1] First Season Releases	YIELDS AND CONSERVATION COSTS[2]						Remarks
							STRAIGHTLINE		TIDAL BARRIER		TOTAL COMBINED		
							Yield	Conservation Cost	Increment of Yield	Conservation Cost	Yield	Conservation Cost	
		m.g.	ft.A.O.D.	sq. miles	ins.	m.g.	m.g.d.	d/1000g	m.g.d.	d/1000g	m.g.d.	d/1000g	
C11	Mosedale (Caldew)[3,4]	6,000	935	12.8	80	5,100	30	6.0	-	-	30	6.0	
C12	Haweswater (enlarged) Additional Storage[3]	30,000	890	Pumped Storage from Eden		25,500	150	6.4	-	-	150	6.4	Alternative use regulating Lune. Yield 150 m.g.d. conservation cost 7.4d.
C13	Gelt (Hynam)	5,700	750	14.4	107	4,850	28	6.7	-	-	28	6.7	

Notes:- *1. After consideration of dead water in the reservoir, compensation flow and reservoir refilling conditions.*
2. See para. 20-27 of Appendix IX.
3. Within National Park.
4. Acceptable to Amenity & Planning Sub-Committee of Jellicoe Conference (HMSO 1963).

SUMMARY TABLE I

REGULATED RIVERS

River	D.W.F.	Yield limitation at 2 A.D.F.: Inland Abstr. Points ≈ 345 A.D.Z.	Yield limitation at 2 A.D.F.: Tidal Barrier ≈ 812 D.O.Z.	Scheme	Description of Site	Effective First Season Releases	Straight Line Yield	Straight Line Cons Cost	Tidal Barrier Increment Yield	Tidal Barrier Increment Cons Cost	Total Yield of Scheme Yield	Total Yield of Scheme Cons Cost	Yield limit of Combined Development of Sites	Alternative Uses (if any) Yield on	Alternative Uses (if any) Cons Cost	15 35 New-castle	11 40 Sunder-land	20 100 Tees-side	15 60 West Riding North	20 80 West Riding South	35 120 Hull and Humber-side	11 35 Flint Den-bigh	30 80 Chester	0 35 Liver-pool	8 10 Man-chester	10 45 Preston	16 60 Fylde	15 80 Cumber-land
																DEMANDS AT 1981 AND 2001												
																TREATED WATER COSTS – PENCE PER THOUSAND GALLONS												
	m.g.d.	m.g.d.	m.g.d.			m.g.	m.g.d.	d	m.g.d.	d	m.g.d.	d	m.g.d.		d													
Coquet	100			d1	Barrow Burn	2 000	18	3.2	–	–	18	2.2				11	20											
				d2	River Coquet	2 300	35	3.4	–	–	21	2.8				11	21											
		66	–	d3	River Alwin	2 500	15	3.2	–	–	15	8.8	88			20	22											
Tyne	810			d5	Irthing	12 600	73	1.2	–	–	72	1.3		Ouse 75	1.0	13	15	11	21	27	22							
				K5	Kielderstone	36 000	210	1.8		–	210	1.9		210	0.8	18	16	11	24	28	22							
				K5A	Kielderstone	36 000	216	2.0			210	2.9		210	0.3	15	16	10	27	28	23							
				d6	Saffronside	2 750	22	3.0	–	–	22	3.0				14	11	19	28	29								
				d7	Chirdon Burn	3 000	15	3.0	–	–	15	3.6				16	11	18	28	28								
				d8	Holt	7 000	32	8.0		–	22	8.0				10	16	20	26	22								
				d9	Warks Burn	1 000	9	5.1		–	9	5.1				17	18	21	29	21								
		272	–	d10	Tarset Burn	2 300	12	1.1	–	–	12	7.1	272			20	21	23	31	33								
Wear	210			K11	Existing Derwent Stage I	1 200	11	2.8	–	–	11	2.0		Ouse		17	18	19	30	25	25							
				d12	Witton-le-Wear	18 100	91	3.5	–	–	91	2.8		81	2.1	11	15	18	25	26	21							
				K12	Browney Stage I	2 120	12	1.0	–	–	12	3.5				18	11	19	27	30	25							
				K13	Bedburn	3 000	22	7.0	–		22	1.0				21	14	18	28	28	30							
				K15	Browney Stage II	8 000	80	10.1	–	–	80	10.1				28	22	22	21	32	28							
				d16	Middlehope	1 000	3	12.0	–	–	0	23.0				27	25	21	30	31	31							
		12	–	d11	Existing Derwent Stage II	2,100	18	15.0	–	–	18	13.8	72			20	27	29	31	38	32							
Tees	422			d18	Middleton	17 000	80	8.1			80	8.1		Ouse 98	8.2			17	23	25	28							
				K19	Egglestone Burn Stage I	2 100	10	1.0			10	1.1		12	7.8	25	22	18	21	28	22							
				K20	Upper Bruts	1 200	8	7.2	–	–	8	1.1						18	30	21	22							
				d21	Upper Maize Beck	2 000	10	8.3	–	–	10	3.2		25	0.8			12	26	31	23							
				K22	Egglestone Burn Stage II	2 000	22	12.0	–	–	15	12.0						28	25	32	28							
				d23	Sedshope	1 100	8	18.1			8	18.1						23	28	25	35							
		88*	–	K24	Heightingless	831	4	16.1	–	–	4	16.0	20					27	33	38	35							
Yorkshire Ouse	1 100			Y1	Existing Gouthwaite	1 320	8	8.2	–	–	8	0.2							17	18	18							
				Y2	New Gouthwaite	3 100	36	2.0	–	–	34	2.2							21	22	11							
				Y3	Bishopdale Stage I	7 000	45	8.1			45	8.1							22	22	18							
				Y4	Arkle Beck	7 500	40	8.8			44	8.5							22	22	11							
				Y5	Birkby Nab	3 100	30	8.0	–	–	30	8.8							22	25	18							
				Y6	Bishopdale Stage II	11 850	85	6.8	–		20	8.8							21	20	21							
				Y7	Snaizeholme Stage I	8 000	20	5.8			28	8.9							30	31	25							
				Y8	Wisdon	5 050	34	12.2	–	–	34	12.2							30	32	27							
				Y9	Snaizeholme Stage II	8 500	20	18.8			26	11.2							22	24	22							
		320	–	Y15	Marsett Moor	1 100	2	20.0	–	–	4	20.0	311						37	39	20							
Wharfe	365			Y12	Existing Washburn	1 350	4	0.4	–		8	0.0							13	18	18							
		104	–	Y12	Grimwith	3 810	21	8.5	–	–	21	8.5	27						18	22	18							
Yorkshire Derwent	223	–	112	Y13	Farndale	8 200	20	11.5	22	0.2	42	8.2	87						21	23	18							
Clywd	125			C1	Brenig (large) part	1 720	10	8.8	–	–	10	1.0										12						
				C2	Tabu Wells	100	3	5.8	–	–	3	5.6										20						
		45	–	C3	Upper Clywd	1 230	10	13.8	–	–	10	12.2	29									20						
Dee	100			C4	Existing Llyn Celyn	1 020	4	0.1	–	–	4	0.1										11	12	13	15			
				C5	Dee Augmentation	1 200	1	0.1	–		1	0.1																
				C6	Brenig (large) part	18,020	10	2.0			10	3.0										20	10	16	18			
				C7	Terch	2 500	20	8.9			20	2.8										23	11	19	22			
				C8	Airmon	7 000	80	7.8	–		81	1.4										24	10	21	22			
		250	–	C9	Existing Alwen	100	0	0.2	–	–	2	0.3	133									25	20	22	20			

SUMMARY TABLE I (continued)

River	A.O.F.	Yield Limitation at 77.0 F		Scheme	Description of Site	Effective First Season Release	Yields and Conservation Costs						Yield Limit of Combined Development of Sites	Alternatives (if any)		DEMANDS IN 1981 AND 2001												
		Inland Abstr. Points = 300 T.D.F.	Tidal Barrier = 815 A.O.F.				Straight-line		Tidal Barrier Increment		Total Yield of Scheme			Yield	Cons Cost	15 57	15 40	20 150	15 65	20 40	30 120	15 35	30 60	0 15	0 20	10 45	15 50	15 40
							Yield	Cons Cost	Yield	Cons Cost	Yield	Cons Cost				TREATED WATER COSTS – PENCE PER THOUSAND GALLONS												
																Newcastle	Sunderland	Teesside	West Riding North	West Riding South	Hull and Humberside	Flint Denbigh	Chester	Liverpool	Manchester	Preston	Fylde	Cumberland
		m.g.d.	m.g.d.			m.g.	m.g.d.	d.	m.g.d.	d.	m.g.d.	d.	m.g.d.															
Wyre	125	83		L22	Abbeystead Storage	860	5	2.5	–	–	5	2.6	27														13	
				L7b	Wyre Upper	3 400	20	8.1	–	–	20	8.1															17	
Ribble	415			L27	Catelling Longridge	–	2	2.2	–	–	2	1.7														15		
				L7b	Underground Storage	860	8	7.7	–	–	7	1.7		Wharfe										16	77	16	13	
				L21	Stock Beck	680	8	7.8	–	–	7	7.8		60	5.0				12	30	22			17	20	18	18	
				L26	Hellifield	15 300	80	7.0	–	–	82	7.0							10	29	16			16	29	12	17	
				L28	Hodder Upper	17 180	70	3.1	–	–	10	2.1							23	27	22			18	70	17	17	
				L31	Bleakhill Beck	1 170	7	3.1	–	–	7	2.1							25	22	23			19	21	18	18	
				L21	Whiteclaw	1 535	7	7.8	–	–	8	8.8												13	17	18		
				L37	Croasdale	1 780	8	8.8	–	–	8	8.8							26	31	27			23	27	22	11	
				L33	Dunsop	2 300	10	7.7	–	–	10	7.7							29	37	20			27	26	25	23	
				L36	Langden	2 800	22	7.8	–	–	22	7.8							26	37	17			25	27	24	23	
		130	–	L77	Skirden Beck	7 500	11	10.0	–	–	17	10.8	136						23	29	20			36	28	25	20	
Lune	788			L12	Roeburn	2 300	15	1.1	15	1.1	20	1.4							30	28	71			31	71	18	18	
				L17	Dee	1 900	16	1.0	20	1.1	10	1.5							32	20	27			20	71	19	10	
				L13	Roeburn (Whitendale)	770	8	1.7	1	1.7	7	1.8							23	71	27			21	72	18	17	
				L14	Underground Storage	867	5	7.7	1	1.7	7	7.8												21	72	18	13	
				L18	Flake Bridge	8 800	28	8.1	8	1.7	36	7.8							73	77	28			33	78	22	11	
				L16	Birk Beck	1 400	8	8.8	–	–	8	5.0		Wharfe					26	35	78			26	75	23	21	
				L17	Greta	8 100	36	8.7	–	–	36	8.7		36	8.8				27	26	22			73	26	27	30	
				L18	Hindburn Upper	7 200	17	7.8	–	–	17	5.5							38	20	26			27	26	23	11	
				L15	Borrow Beck	17 100	80	7.0	–	–	70	7.0							28	32	77	78	38	26	27	20	72	
				L20	Barbon Beck	1 300	14	7.1	–	–	14	7.1							28	72	11			28	27	27	72	
				L21	Langdale	1 120	7	8.0	–	–	7	9.0							26	36	77			25	77	24	22	
		–	188	L21	Sunderdale	1 000	8	10.7	–	–	8	10.3	148						35	38	70			33	37	30	30	
Kent	320			L6	Sprint Lower	8 200	53	1.7	20	3.8	83	7.7		Wharfe 83	10.5				18	77	75			78	28	13	28	
				L8	Mint (Mint Bank)	2 400	20	7.3	–	–	70	7.7												77	28	29	28	
				L8	Kent Lower	8 800	32	7.8	–	–	77	2.8												78	28	28	71	
				L1	Peasey Beck	5,700	30	3.0	–	–	39	3.0												25	70	77	71	
				L6	Lupton Beck	3 200	15	7.0	–	–	10	2.7												75	78	77	21	
				L6	Bannisdale Lower	2 100	12	7.8	–	–	12	7.8												28	29	27	77	
				L7	Killington (Part Only)	11 000	70	8.1	–	–	70	7.1												30	30	29	70	
		–	171	L10	Arnside Impoundment	15 700	87	12.0	–	–	90	11.0	171											33	34	32	29	
Leven	300			L7	Winster	15 200	70	7.8	71	2.7	71	7.7												77	26	23	78	
		–	156	L7	Killington (Part only)	16 400	87	7.1	–	–	87	7.1	183									36	37	78	39	28	36	
Duddon	118	–	87	L1	Duddon	5 000	32	7.0	10	0.7	42	7.0	87											25	78	27	71	17
Derwent				C1	Cocker	18 700	90	1.6	82	1.1	135	1.0																16
				C1	Derren	17 300	70	8.8	–	–	60	8.6																17
				C7	Newlands Beck	3 000	10	7.1	–	–	10	5.1																17
				C4	Carr Beck	1 700	10	7.7	–	–	10	8.7																17
				C5	Eastrigg Beck	2 000	10	8.0	–	–	14	8.0																18
		–	718	C6	Thirlmere	1 800	80	–	33	–	77	–	718															
Calder Ehen & Irt	140			C1	Wastwater	1 000	8	1.3	–	–	5	1.5																11
				C?	Ennerdale Beck	1 100	8	0.7	–	–	4	0.7																16
				C6	Ehen	2 710	10	1.0	–	–	14	7.8																17
		86	–	C1	Calder	1 126	11	0.7	–	–	12	9.1	38	North Tyne														10
Eden	900				Wobstale (Caldew)	5 100	20	8.0	–	–	20	8.8		38	10.3	22												23
		332	–	C1	Haweswater (enlarged)	28 500	120	6.7	–	–	130	8.8		177	10.7	23												26
				C1	Gelt (Hynam)	8 600	70	0.7	–	–	28	7.7	100	26	11.0	25												77
					[illegible]									Lyne								[illegible]	[illegible]	[illegible]	97	23	12	

SUMMARY TABLE I (continued)

RESOURCES			DEMANDS			AT			1981		AND		2001		
Description of Site	Yields and Conservation Costs Total Yield of Scheme		18 55	15 40	20 100	18 65	60 60	35 120	13 35	30 60	8 65	7 75	15 40	15 50	15 40
			TREATED		WATER		COSTS	-	PENCE	PER	THOUSAND		GALLONS		
	Yield m g d	Cost Net d	Newcastle	Sunderland	Tyneside	West Riding North	West Riding South	Hull & Humberside	Flint Denbigh	Chester	Liverpool	Manchester	Preston	Fylde	Cumberland
Morecambe Bay	450	3.50		34	28	26	31	28	31	27	23	24	22	19	
Solway Firth 1st Stage	300	8.30	23	22	24	33	37	33							17
Dee Estuary	250	4.78							39	19	23	23	25	27	

* See Diagram IX/10

NORTHERN TECHNICAL WORKING PARTY

SUMMARY TABLE II

DIRECT SUPPLY RESERVOIRS

RESOURCES							DEMANDS IN M.G.D													
							In 1981 2001	15 85	35 90	20 120	18 60	20 80	30 120	15 35	30 80	0 85	0 70	15 85	18 50	15 40
							AND TREATED WATER COSTS IN PENCE PER THOUSAND GALLONS													
River System	Ref. No.	Description of Site	Gross Storage m.g	T.W.L ft. A.O.D	Yield m g.d	Conservation Costs d/1000g	at	Newcastle	Sunderland	Teesside	West Riding North	West Riding South	Hull & Humberside	Flint/Denbigh	Chester	Liverpool	Manchester	Preston	Fylde	Cumberland
Coquet	N1	Darrow Burn	1,290	600	4	2.8		15	17											
	N2	River Coquet	3,610	864	15	8.0		16	18											
	N3	River Alwin	1,400	715	5	5.5		17	19											
Tyne	N4	Irthing	6,200	600	24	5.1		13	13	15	30	32	26							
	N5	Otterstone	16,200	587	65	1.5		14	16	17	32	34	26							
	N6	Saffronside (a)	4,400	696	30	6.2		15	19	19	34	36	31							
	N7	Chirdon Burn	2,380	500	8	4.5		18	20	20	35	37	31							
	N8	Halt (A)	6,300	570	37	3.1		19	20	21	35	37	32							
	N9	Warks Burn	1,630	695	6	6.8		18	19	22	34	36	31							
	N10	Tarset Burn	2,700	650	9	9.6		22	24	24	39	41	35							
Wear	N12	Wilton-le-Wear (c)	11,500	402	33	5.0				15	28	30	25							
	N13	Brownsey	1,100	654	4	6.1				15	29	31	25							
	N15	Bedburn (d)	2,450	600	8	8.5				18	30	32	26							
	N16	Middlehope (c)	700	1,230	3	20.4				31	39	41	30							
Tees	N18	Middleton (B)	17,300	875	68	1.2				17	23	27	22							
	N19	Eggleston Burn	1,530	1,130	5	8.1				20	26	28	25							
	N20	Upper [illegible]	1,220	850	7	6.5				17	25	27	23							
	N21	Upper Maize Beck (b)	7,410	1,757	12	12.2				19	26	28	26							
	N23	Hudeshope	1,140	995	4	16.0				27	36	36	33							
	N24	Sleightholme	1,100	1,200	6	11.9				23	29	31	29							
Yorkshire Ouse	Y3	Bishopdale	11,710	603	45	6.2					21	26	21							
	Y4	Arkle Beck	4,590	650	16	4.1					22	24	28							
	Y6	Kirkby Moss	3,070	271	18	7.3					23	27	26							
	Y7	Snaizeholme	5,330	1,000	20	11.1					26	29	25							
	Y8	Aisdon	4,090	1,000	31	14.5					32	31	31							
	Y12	Grimwith	1,963	607	5	7.7					22	24	23							
Yorkshire Derwent	Y13	Farndale	3,260	499	12	15.8							21							
Clwyd	D5	Upper Clwyd	560	670	3	15.0								23	21					
Dee	D1	Brenig	1,500	1,165	6	9.6								15	16					
	D6	Tarsh	1,270	1,035	5	8.6								17	17					
	D7	Hirnant	2,950	938	11	6.7								19	18					
Ribble	L27	Stock Beck	850	801	5	2.2								26	19	16	18	13	14	
	L28	Hellifield	18,090	495	72	1.7					18	24	27		22	18	19	17	14	
	L29	Hodder Upper (c)	16,600	920	46	3.3								28	21	16	18	16	14	
	L30	Stanshill Beck	730	615	3	3.5									21	14	18	15	14	
	L32	Crossdale (d)	1,330	600	5	10.6									28	24	26	23	22	
	L33	Dunsop (d)	3,100	523	12	10.7									28	24	26	25	22	
	L34	Langden (d)	2,860	600	11	10.8									28	24	26	23	23	
	L35	Skirden Beck	1,800	540	7	11.3									29	25	27	23	23	
Wyre	L24	Wyre Upper	2,500	500	20	3.9								28	22	17	20	17	13	
Lune	L3	Killington B	20,800	675	130	19.2					36	42			30	36	30	33	16	
	L12	Dee	8,270	443	30	1.7									29	18	21	18	16	
	L15	Flake Bridge	2,997	768	11	3.3									23	19	21	18	14	

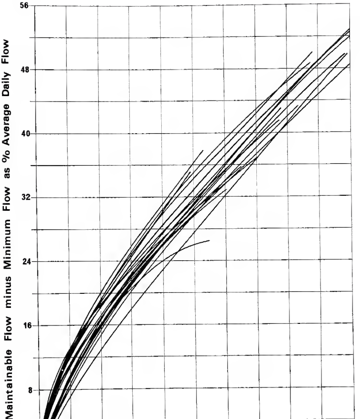
RESOURCES							ORGANIC IN O G D.													
							In 1981 2001	18 80	15 40	25 100	18 77	20 85	35 120	15 58	30 80	9 25	9 75	17 89	15 57	18 40
River System	Ref No	Description of Site	Gross Storage	TWL	Yield	Conservation Costs	ATO TREATED WATER COSTS IN PENCE PER THOUSAND GALLONS													
			M g	ft. A O D	m.g.d.	£/1000g	et	Newcastle	Sunderland	Tyneside	West Riding North	West Riding South	Hull / Humberside	Flide/ Lancsh.	Chesier	Liverpool	Manchester	Preston	Fylde	Cumberland
Lune	116	Birk Beck	7 950	465	18	4 2									25	18	25	20	17	
	117	Grain	3 720	777	14	7 7									23	16	17	17	18	
	118	Tinthorn Upper	7 [illegible]	618	70	8 8									26	17	77	71	18	
	119	Borrow Beck	3 820	7/0	70	8 7									27	21	22	17	17	
	L20	Barbon Beck	1 [illegible]	711	7	7 9									27	27	23	77	18	
	L21	Langdale	2,800	878	5	8 8									29	75	26	78	77	
	L22	Bowderdale	875	888	5	/4 7									37	30	71	29	77	
Kent	18	Tarlsi Lower	8,277	572	18	1 8									22	17	20	17	17	
	15	Tinl (Heal Bank)	8 [illegible]	611	21	7 1									78	20	23	28	17	
	18	Kent Lower	8 770	327	18	8 2									78	21	27	71	17	
	17	Pooney Beck	7 [illegible]	307	18	8 8									78	77	28	71	17	
	L8	Lupton Beck	7 120	708	8	8 3									78	77	21	71	17	
	L9	Borrowdale Lower	7 [illegible]	582	13	8 7									77	28	77	25	21	
Leven	17	Winster R E	12,[illegible]	106	70	2 7								77	23	18	27	10	18	
Duddon	14	Duddon R	8 200	740	34	4 8								72	18	22	28	21	17	17
Calder Ehen Irt	C7	Wastwater E	1 300	777	14	8 7								33	26	75	26	78	22	19
	C8	Mosedale Beck E	1 800	900	8	7 [illegible]														16
	C9	Bleng R	1 340	877	8	8 5														27
	C10	Calder E	2 [illegible]	825	13	8 7														18
Derwent	C1	Bucker	15 [illegible]	260	59	1 7														13
	C2	Marron E	18 [illegible]	415	77	8 1														17
	C3	Tonlands Beck	3 [illegible]	950	16	8 8														18
	C4	Carr Beck	985	315	7	11 8														27
	C5	Lodrigg Beck	775	788	7	7 9														23
Eden	E11	Mosedale (Ogilvie)	8 750	911	16	7 7								36	31	25	78	77	25	71
	E12	Keensmoster (enlarged) E	90 000	860	186	18 8								38	37	78	71	29	37	
	E13	Gelt (Hynam)	5 700	780	28	7 7								30	37	31	31	29	78	77

Notes: *The catchments of sites marked with small letters lie within larger catchments serving sites marked with corresponding capital letters. Consequently yields from each associated scheme cannot be added*

Treatment costs for sites marked E are taken at 36d per 1000 gallons: others at 46d per 1000 gallons

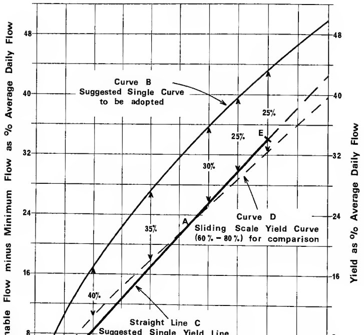
⊕ Pumped or partially pumped storage

Maintainable Flow minus Minimum Flow Curves as plotted from the River Authority Curves

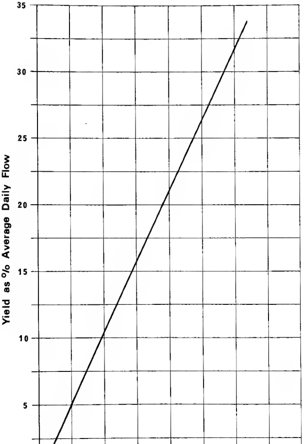


Diag. IX / 2

Maintainable Flow minus Minimum Flow and Yield Curves for Inland Abstraction Points

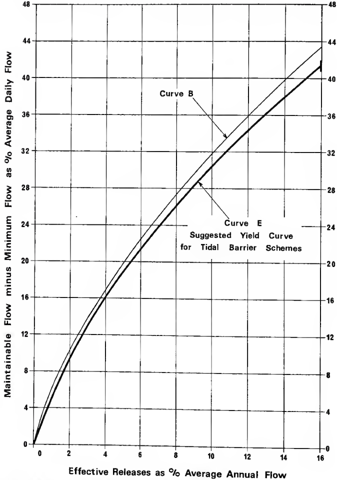


Yield / Storage Relationship for Inland Abstraction Points

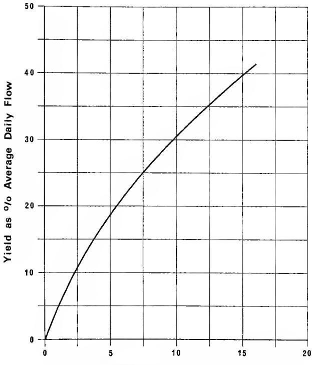


Diag. IX / 4

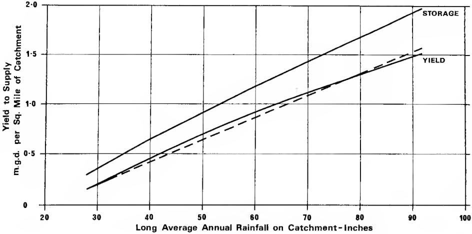
Maintainable Flow minus Minimum Flow and Yield Curves for Tidal Barrier Abstraction Points



Yield / Storage Relationship for Tidal Barrier Abstraction Points



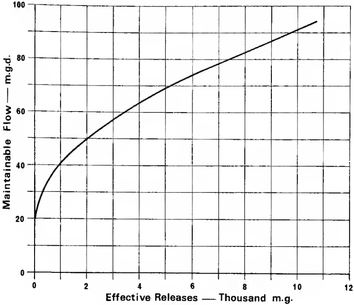
STORAGE AND YIELD
FOR DIRECT SUPPLY RESERVOIRS

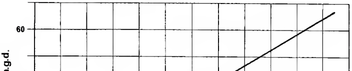


NOTES Storage and yield curves are based on the assumption that the reservoir refills at the end of the three driest consecutive year period It is assumed that 30 per cent of the gross yield is reserved for compensation The broken line is the Lapworth Yield Line corresponding to the storage curve shown, assuming that R F - R O. = 16 ins. and that the yield to supply is 70 per cent of the gross yield It is shown only for comparative purposes.

NORTHUMBRIAN R.A.

R. Coquet at Guyzance average daily flow 195 m.g.d.



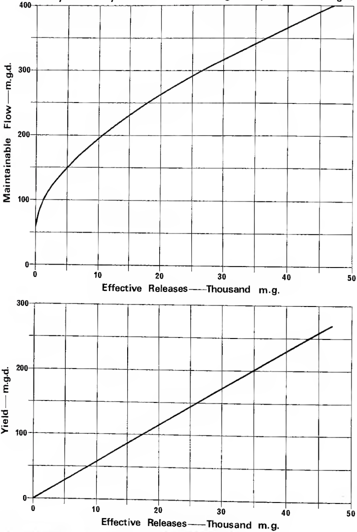


Diag. IX/8

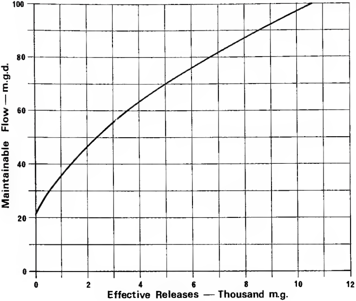
NORTHUMBRIAN R.A.

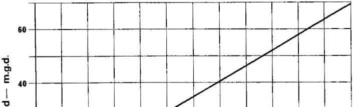
R. Tyne at Bywell

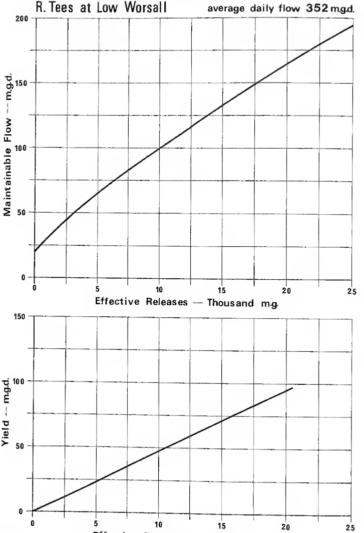
average daily flow **800** m.g.d.



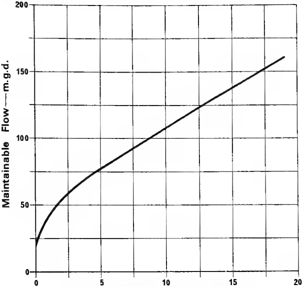
R. Wear at Croxdale average daily flow **210** m.g.d.

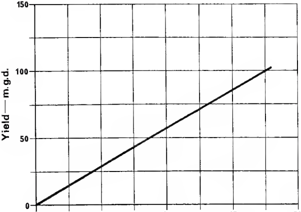





R. Tees at Low Worsall
average daily flow 352 m.g.d.
Maintainable Flow — m.g.d.
0
50
100
150
200
0
5
10
15
20
25
Effective Releases — Thousand m.g.
Yield — m.g.d.
0
50
100
150
0
5
10
15
20
25
Effective Releases — Thousand m.g.

R. Wharfe at Flint Mill average daily flow 308 m.g.d.

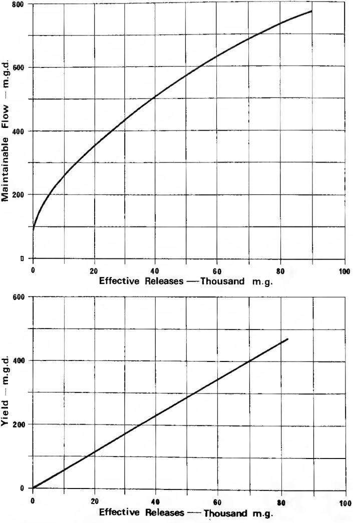




Diag. IX/12 **YORKSHIRE OUSE AND HULL R.A.**

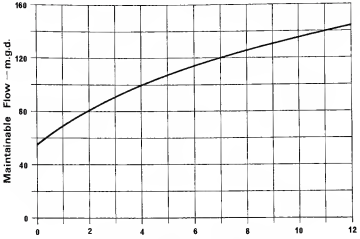
R. Ouse at Cawood

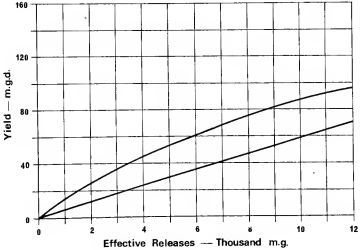
average daily flow 1400 m.g.d.



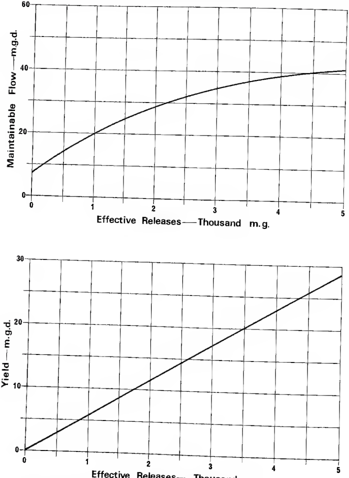
Diag IX/13

R. Derwent at Stamford Bridge average daily flow 273 m.g.d.





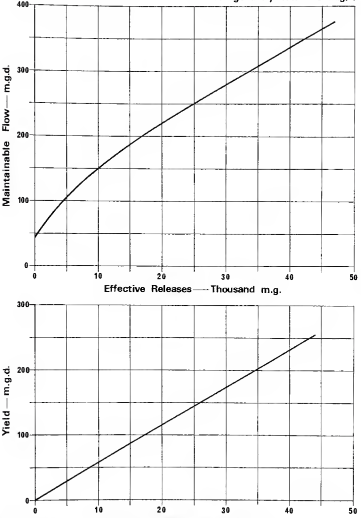
R. Clwyd at Pont-y-Cambwll average daily flow 126 m.g.d.



DEE AND CLWYD R.A.

R. Dee at Chester

average daily flow **740** m.g.d.

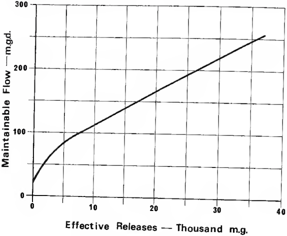


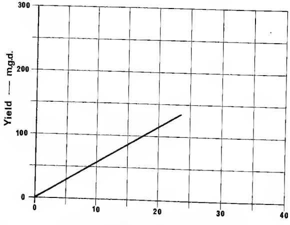
Diag IX/16

LANCASHIRE R.A.

R. Ribble at Hodder Foot

average daily flow **406** m.g.d.



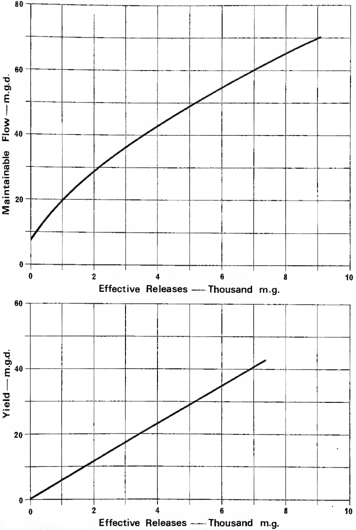


Diag. IX / 17

LANCASHIRE R.A.

R. Wyre at St. Michaels

average daily flow **125** m.g.d.

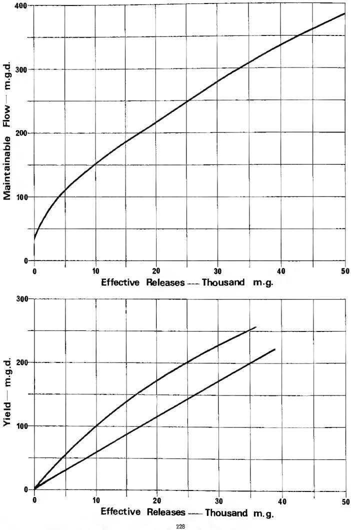


Diag. IX/18

LANCASHIRE R.A.

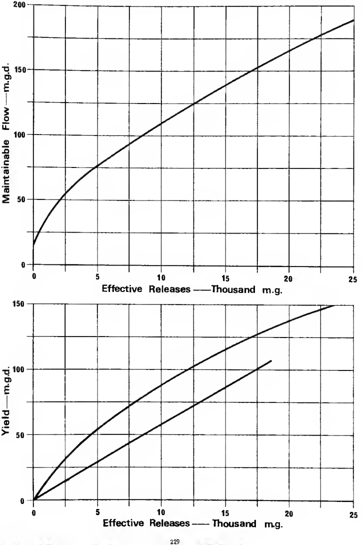
R. Lune at Halton

average daily flow **655** m.g.d.



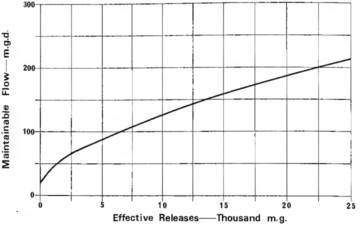
Diag. IX/19

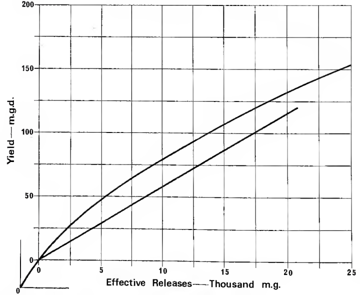
R. Kent at Arnside Viaduct average daily flow 320m.g.d.



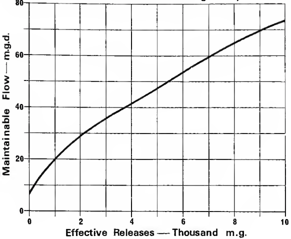
R. Leven at Greenodd

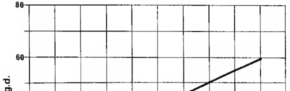
average daily flow **388** m.g.d.





R. Duddon at Duddon Viaduct average daily flow 114m.g.d.

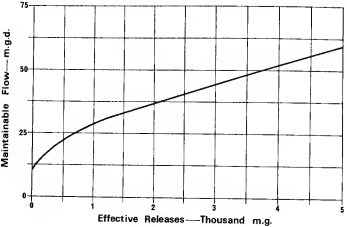


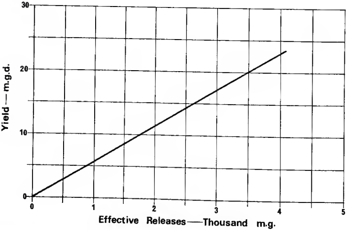


Diag. IX/22

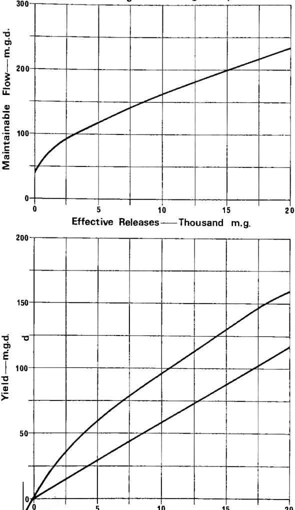
CUMBERLAND R.A.

R. Calder, Bleng and Irt average daily flow 140 m.g.d.



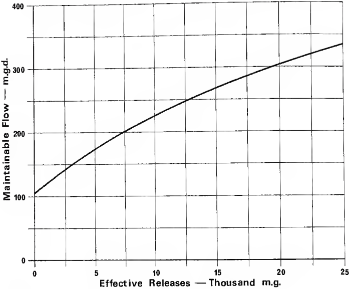


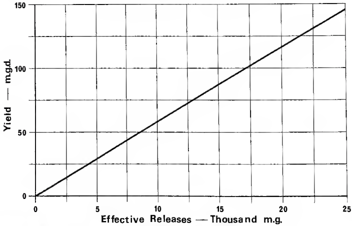
R. Derwent at Workington average daily flow 514 m.g.d.



R. Eden at Carlisle

average daily flow 980 m.g.d.





APPENDIX X

APPENDIX X: ANALYSIS OF PROGRAMME COSTS

1. Appendix IX contains particulars, including estimated costs, of the resources which can be made available to meet needs in the north. These have been assembled into water conservation programmes, several of which have been summarised in Chapter 7. In this Appendix we describe the evolution of these programmes in rather more detail and explain how the costs have been processed to facilitate comparison.

2. It has been the object of these studies to determine the least costly way in which sources of a certain kind could be developed and linked up into a system to serve the needs of the north as a whole - expressed in terms of future need at thirteen centres - and to compare this with the least costly way in which we could use sources selected according to some other criterion - for instance inland sources on the one hand and estuary sources on the other.

3. Comparisons have been made in this way because when one is free to 'optimise' the use of water resources over a whole region - sharing the use of a given source widely for a time, superseding this with a different set of allocations when a new source is brought into service, perhaps using a linking aqueduct for different purposes from time to time - it is no longer sufficient to assess the merits of sources one by one. One must assess the merits of a network and of the programme which brings the network into being.

4. Most of the programmes are designed to meet a fixed pattern of future demands and our comparisons show their relative effectiveness, in terms of cost, for doing this. Our terms of reference have not required us to assess the benefit to the community of meeting expected demands for water or to assess how the general demand for water might respond to a change in its price.

5. It is of course theoretically possible that a wide ranging economic study would lead to the conclusion that water demands are being met at too great a cost in relation to the community's other needs. But the techniques which would enable us to test this theory have not yet been established and for reasons touched on in our introductory chapter - in particular that we foresee no significant change in the real costs of water - we do not think that it would have any important consequences in this field.

6. We have, however, run some programmes for different levels of demand to test the sensitivity of our conclusions to errors in the demand estimates. And in the case of certain industrial demands - especially heavy cooling water demands by riparian industry - which will clearly be sensitive to possible price changes in certain localities, we have assumed that by and large these will grow where cheaper water is readily available.

7. The various schemes will affect the environment and other river users in different ways and final comparisons must take this into account. The difficulties of assessing possible supplementary benefits and losses are reviewed in Chapter 6 and Appendix VI: reliable techniques do not yet exist for quantifying these items as between one set of schemes and another. It would therefore be misleading to attempt to arrive at some arithmetical total of net benefits to set beside the costs of each strategy; instead, an array of cost differences has been given so that the cost implications of various choices can be seen.

8. If and when convincing studies of supplementary benefits and costs are made - perhaps for the estuary schemes - these can most easily be integrated into the 'cost-effectiveness' study of the water resources network itself by adjusting the costs of schemes to take account of any net surplus of non-water benefits or costs. This should enable valid comparisons to be made without in any way prejudicing the question of how the costs of such a scheme will be shared out in due course.

9. Growth of demand has been estimated to the end of the century. Since the schemes considered are of widely varying sizes, however, the incidence of expenditure over this period will vary widely between different programmes. Some will call for investment in relatively few large instalments and will carry a lot of surplus capacity in between; others will call for gradual expenditure more closely matching the growth of demand. Moreover, the capacity in some programmes will inevitably overlap the end of the period.

10. To meet these problems and to enable us to make valid comparisons of costs incurred at different dates we have used the technique of present value discounting, taking 1970 as the base date and using the discount rate of 8% p.a. recommended by the Government in the White Paper 'Nationalised Industries - A Review of Economic and Financial Objectives' : Cmnd 3437. In other words, we have converted all expenditures to their 1970 value by substituting the sum which, invested in 1970 at 8% compound interest, would realise the required amounts by the expenditure dates.

11. It is perhaps worth emphasising here that this is an exercise in the optimum use of real resources - labour and materials - for water resource development in the north as a whole. It is not concerned with the optimum arrangements for a part of the region, if at the expense of the whole; still less is it concerned with the arrangements for financing expenditure or the interest rate payable by any promoting authority. Indeed, its specific object is to identify the merits of each long-term programme for the community as a whole irrespective of the nature of the promoting body and of the terms on which each item is financed. These matters will of course require consideration at the proper stage: but such consideration cannot offer guidance on the long-term commitment of real resources.

12. The discount rate is a measure of the preference for deferring expenditure to another day, so releasing more of to-day's resources for other worthwhile ventures. Its ultimate function is to help allocate investment most wisely and most fruitfully over the whole field and to this end it is most important that a common rate be used in similar circumstances. Nevertheless, changes are possible in the assessment of the proper rate even for the long term and accordingly we have tested the effect on some of our programmes of substituting rates other than 8%.

13. Another point which deserves some comment is the changing level of prices. General price changes have no relevance to the commitment of real resources: a general price rise is better regarded simply as a shrinkage of the unit of measurement - virtually a translation to another currency unit. We have expressed all our costs in terms of the fixed unit which we have called the $£_p$ - i.e. in terms of the present price level. Relative price movements, on the other hand, might affect the relative real costs of programmes and we have tested this to some degree by radically varying the price of electric power relatively to other prices.

14. Provided that we could compare various patterns of schemes all of which would meet the growth of need until the year 2001 exactly, and continue to meet the pre-2001 sector thereafter, comparison of their costs in this way would suffice. Where there are large discrepancies between programmes, however, the result bears unfairly on schemes which have much residual 'growth-capacity' after 2001. If the growth in demand were extrapolated until the 'growth-capacity' of each programme was exhausted there would no longer be a common basis of comparison between programmes: i.e. some programmes would cover a longer period of growth than others.

15. One way of dealing with this is to determine the ratio of 'present value' of expenditures and 'present value' of the demands during the period analysed, i.e. future water demands are reduced to an equivalent 1970 value by discounting their worth at 8% per annum compound interest in the same way as we discount expenditures and the ratio of the two discounted amounts is determined - the unit present value[1].

16. As a variant on this the cost and demand 'ceilings' reached, when the growth potential of any programme is exhausted, may be continued level to perpetuity before reduction to present value, allowing for regular replacements of assets at due dates.

17. An alternative procedure would be to curtail the outlay on overlapping items either by arbitrarily reducing their size, by taking account only of capital charges due by 2001, or by allocating a 'salvage value' at that date.

18. It is considered that the simplest procedure is to scale down the output and cost of each terminal scheme pro rata to that required in 2001. In effect this implies that demand will go on growing and that the remainder of expenditure on large schemes will yield returns in due course. This procedure does not furnish an exact comparison but minor discrepancies towards the end of the programme will not distort the results appreciably.

19. Before comparing the more favourable programmes of development in this way a preliminary sorting of schemes was done by determining firstly for each regulated river basin and subsequently for each conservation scheme a typical conservation cost per thousand gallons of yield and typical treatment and conveyance costs to each demand centre.

20. The unit conservation costs were based on estimates of the cost of storage works and assumed conditions for abstraction of water to supply; they ranged from less than one penny to 20 pence per thousand gallons of yield at full output. For bulk treatment and delivery the overall treatment costs ranged from 2½ pence to 6 pence per thousand gallons, capital cost of large aqueducts (say, 72 inch diameter) was put at one penny per thousand gallons per ten miles of delivery and overall pumping cost at one penny per thousand gallons per hundred feet of lift. These rates are analysed and considered in greater detail in Appendix VIII.

21. As will be seen from Appendix VIII, the unit rates for various works allow for capital charges based on a 6⅛% rate of interest and the usual loan periods (equated with asset replacement periods) for public works borrowing and they may readily be compared with those adopted in a number of current reports on water engineering works. On the other hand, subsequent analyses in which actual outlays are discounted at 8% will not reflect exactly the results of these preliminary analyses based on conventional unit rates.

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[1] *Such a device was used in the Dee Crossing Study - Phase 1. H.M.S.O. 1967.*

22. By linking sources and demand centres in all possible patterns the overall costs of operating each pattern to meet the assumed demand at each centre at certain target dates - 1981, 1991 and 2001 - could be compared and the least costly arrangements determined. This was done, using a simple computer programme, and it gave a general idea of the overall daily costs of a regional conservation and delivery system at full stretch (e.g. a year such as 2001) and the extra costs of departing from the optimum free choice - e.g. by eliminating small conservation schemes in an effort to reduce numbers of schemes, by proscribing development in national parks and areas of outstanding natural beauty - and so on.

23. The first general analyses were confined to a series of selections of source rivers to meet the public water supply deficiency with varying constraints imposed against rivers preferred in the preceding selections. The delivered water costs used in these analyses were based upon a mean conservation cost for each complete river basin and a mean treatment cost of 4½ pence per thousand gallons. A summary of results together with some typical data sheets is given in Tables X/2 and X/3.

24. The analyses underlined the obvious importance of transmission costs and indicated that the demands could be met at the year 2001 at an average price, in terms of conventional unit costs, of between 18 and 24 pence per thousand gallons of water delivered into terminal storage at thirteen notional demand centres. The relatively narrow price differential, with a wide range of source constraints, also indicated the need for a close scrutiny of cost elements where significant differentials might exist, such as the cost of treatment of river supplies for particular destinations.

25. Further selections were made of minimum cost solutions using the data for individual source works, including estuary works, given in Summary Tables I and II of Appendix IX in which the delivered water cost includes weightings for special treatment (see Appendix IV). Constraints were imposed to produce a variety of alternative solutions as indicated in para. 2 and average costs ranged from under 18 pence per thousand gallons for the optimum free choice to 23 pence for a system making the maximum use of the three estuary sources (Dee, Morecambe, Solway). The form in which results were obtained is indicated in Table X/5 and a summary of the computer selections is given in Table X/4.

26. Apart from giving these crude indications of the effectiveness of alternative solutions the computer analyses were a useful guide to the selection of sources to serve Lancashire and Yorkshire where the heaviest demands were concentrated and for which the relative merits of various sources were by no means obvious. In addition it was noticeable that the minimum cost solutions for systems of inland developments would require considerable flexibility in the use of resources, so that large sources with favourable conservation costs could be deployed over a wide distribution area and re-deployed to different destinations at later dates.

27. Computer programs were not readily to hand, nor were we able to develop satisfactory 'short-cuts', to weight the system of choice for periods when large schemes had redundant capacity, to build continuity into the growth of the systems or to give credit for adaptability to change, although several devices were considered. We were thus unable to continue to analyse the system on a completely general basis so as to determine which of the possible programmes of development would involve the least overall cost in present value terms and the penalties of departing from this optimum.

28. Such a general analysis remains the ideal, of course. It should take account of the differing probabilities of failure to meet demand which are inherent in the various types of programme. This is a function not only of their hydrological characteristics but also of their redundant capacities and of their flexibility for coping with variations in the pattern of demand.

29. From this point onward resort has therefore been made to comparison of a limited number of selected programmes, made up in the light of the general analysis described above. Programmes to meet estimated regional needs to 2001 have been developed and costed to give both arithmetical and 'present value' (1970) totals in accordance with the ground rules given earlier. The projected annual outlays have been plotted against time in arithmetical and present value (distorted) plots to give visual comparisons of effective outlay in terms of the areas under the curves (Figs. 1-10(c)).

30. For each of the selected programmes of development discussed in Chapter 7 the cost pattern has been built up by taking into account the actual incidence of each capital outlay and the annual expenditure on power and maintenance. The cost elements do not correspond exactly with the simple unit rates we used earlier for water conservation and movement because more account has been taken of such things as probable pipe size (the unit rate of one penny per thousand gallons per 10 miles for 72" aqueduct being roughly doubled for 36" and trebled for 24" aqueduct), and the scale effect - diminishing unit cost with increasing size - of most items of civil engineering construction (see Appendix VIII).

31. Pipes have been replicated at optimum intervals of ten to twelve years (as was implied in the overall unit rate for movement in 72" pipes) and other equipment is assumed replicated at roughly optimised intervals. Conservation works (dams) have been assumed staged where this would be cheaper in present value terms. The problem of residual growth capacity in any pattern at the end of the century has been dealt with as indicated in para. 18 above, i.e. by determining the proportion of yield of the last scheme needed to reach the year 2001 and taking a similar proportion of its cost.

32. For the 'present value' calculations all operating costs have been projected in perpetuity at level rates after 2001 and allowance has been made for renewing capital assets periodically in perpetuity: this irons out discrepancies arising from the relative newness of certain works in 2001. (This cannot be done with arithmetic totals of outlay, of course, since they do not converge to limited amounts.)

33. The total expenditures on four of the programmes have also been discounted at 5% and 11% to give the values tabulated below:-

Prog. No.	Description	Programme Costs $£_p$ million			
		Total Outlay	Expenditure discounted in perpetuity at rates of		
			5%	8%	11%
1	Direct Supply – Free selection of inland reservoirs	426	259	159	112
3	River Regulated Systems Inland reservoirs outside National Parks	372	232	132	88
5	Eight large inland reservoirs	380	236	136	92
9	One estuary (Morecambe)	409	254	143	96

The tabulation indicates that the order of selection of these different strategies is not affected by varying the discount rate.

34. The effect of a substantial change in relative prices on these four programmes has also been investigated by considering.

   (a) a gradual reduction in electrical power cost linearly to half of its present rate by 2001 and maintaining it level thereafter;

or conversely

   (b) a gradual increase in power cost to twice its present rate by 2001 and maintaining it level thereafter.

Applying these variations to the programmes listed below is not a simple matter of varying the total costs of power consumed. With increasing power costs economic pumping velocities are lowered and pipeline optimum sizes are increased for a given discharge and the whole of the transmission network should be re-calculated and re-costed. The effect of these variations has been assessed by sample calculations on representative nests of mains and the resultant mean variations in total transmission cost applied to the original programme costs to give the results tabulated below:-

Prog. No.	Description	Programme Costs $£_p$ million					
		Relative Costs Unchanged		Power Costs halved at 2001		Power Costs Doubled at 2001	
		Total Outlay	1970 Value	Total Outlay	1970 Value	Total Outlay	1970 Value
1	Direct Supply – Free selection of inland reservoirs	426	159	417	155	451	168
3	River Regulated Systems Inland reservoirs outside National Parks	372	132	356	125	415	146
5	Eight large inland reservoirs	380	136	363	129	425	150
9	One estuary (Morecambe)	409	143	388	134	465	161

35. Again, as in the comparisons made with varying discount rates, the relative price change has not changed the order of selection of programmes and hence the comparisons in Chapter 7 based on fixed relative prices are not invalidated. As might be expected the variation has had little relative effect on comparisons in the last three programmes whose transmission systems are more nearly comparable, and the most marked change is that a relative increase in the price of power has narrowed the gap between these three and the direct supply solution which has a lower power element.

36. In Chapter 1 paras. 11 and 12 reference was made to the uncertainties inherent in estimating future demands and the possible repercussions on any long term strategy. The effect of a marked shift in demands east or west of the Pennines has been investigated by

   (a) artificially reducing demands in the north east by about 100 m.g.d. at 2001 and imposing an equal additional demand at Chester at the same date;

and conversely

(b) artificially reducing demands at Chester and Flint/Denbigh by 100 m.g.d. at 2001 and imposing an equal additional demand in the north east.

Basic programmes 1, 3, 5 and 9 have been modified to allow for these variations in demands with the results tabulated below.

Prog. No.	Description	Programme Costs $£_p$ million					
		Basic Programme		Balance of demand shifted to the west		Balance of demand shifted to the east	
		Total Outlay	1970 Value	Total Outlay	1970 Value	Total Outlay	1970 Value
1	Direct supply - Free selection of inland reservoirs	426	159	440	165	431	160[1]
3	River Regulated Systems Inland reservoirs outside National Parks	372	132	387	136	363	128
5	Eight large inland reservoirs	380	136	405	140	360	129
9	One estuary (Morecambe)	409	143	413	143	396	136

The tabulation indicates that these substantial demand variations would not have changed the order of selection.

37. Given the flexibility of deployment of resources which is considered to be an essential part of any long term plan, the development of the system could be adapted to cope with variations of this order in the estimated demands at 2001. Lack of such flexibility would defeat this objective and bring penalties in needless expenditure. An example of rigidity in planning has been investigated by considering the development of a least cost programme equivalent to programme No. 2 - a free selection from all inland sources - but with individual sources tied solely to individual demand districts. The total outlay would be £8 million more and the total discounted cost £12 million more than that of the flexible least cost solution.

38. For the ten basic programmes we have given in this appendix:

(a) diagrams indicating the strategy of development at 2001 and in some cases for intermediate dates at which there is a re-allocation of resources within the programme;

(b) demand/resources graphs, showing the dates of development of the individual sources included in the programme;

(c) graphs of actual and of discounted annual expenditure.

39. In Table X/5 we have given a summary of the estimated costs of the programmes described in Chapter 7 and have indicated:

---

[1] *Demand shift restricted to 70 m.g.d. by disposition of available sources.*

(a) arithmetic sum of outlays to 2001;

(b) ratio of (a) to sum of quantities delivered by 2001 (mean unit cost);

(c) 'Present' (i.e. 1970) value of all outlays to perpetuity;

(d) ratio of (c) to sum of discounted deliveries to perpetuity (present value unit cost or '1970 unit value').

40. It should be borne in mind that:

(a) All the costs quoted relate to a regional convervation, treatment and bulk delivery system for water. They cover costs to a terminal storage reservoir in each of thirteen major 'demand centres' in the north; they do not cover distribution from such centres.

(b) The costs take no account of continued growth of demand after 2001 (projections to perpetuity are flat).

SELECTED

COMPUTER ANALYSES

NOTES

1. The following Tables X/1-X/4 contain summaries and abstracts of the computer selections described in the Appendix paras. 23-26. It should be noted that the demands at the thirteen notional delivery points used for this purpose do not correspond exactly with the final deficiencies summarised in Table H of Chapter 5 nor do all the yields and costs correspond exactly with those given in Schedules II and Summary Table I of Appendix IX. These preliminary analyses of resource allocations were commenced using provisional estimates of final deficiencies and conservation costs while the survey of demands and resources was still in progress. Subsequent modifications have introduced differences in detail but final demands and delivered water costs have not varied sufficiently to invalidate comparisons between the overall unit costs of completed systems of developments derived from the different methods of analysis.

2. Table X/3 also includes summaries of selections of resources to meet different patterns of demand to indicate the effect upon resource selection and overall unit cost of varying assumptions about the growth of industrial demand or the development of isolated sources. Strictly comparable detailed conservation programmes are not available as the analysis indicated the need for a more searching test of the sensitivity of the comparisons made in Chapter 7 to wider variations in the demand pattern. (Appendix X, para. 36).

SUMMARY TABLE X/1

COMPUTER SELECTIONS OF SOURCE RIVERS

Case No.	Rivers and available yields in m.g.d.	Total available Yield m.g.d.	Total Supplies m.g.d.	Date	Cost '000d/day	Cost d/1000 gals.
0	270 Tyne, 73 Wear, 238 Ouse, 45 Oerwent, 110 Oee, 150 Ribble, 205 Lune, 167 Kent, 170 Leven, 216 Cumber'd. Oerwent, 14 Clwyd	1,658	138	1981	2,341	16.9
			421	1991	7,372	17.4
			719	2001	12,869	17.9
1	As case 0 but omit Ouse	1,320	138	1981	2,423	17.6
			421	1991	8,244	19.5
			719	2001	14,794	20.6
2	As case 0 but omit Ribble	1,508	138	1981	2,463	18.0
			421	1991	7,910	18.7
			719	2001	13,805	19.3
3	As case 0 but omit Lune and Ribble	1,303	138	1981	2,487	18.0
			421	1991	7,990	18.7
			719	2001	13,949	19.4
4	As case 0 but omit Lune, Ribble and Kent	1,136	138	1981	2,559	18.6
			421	1991	8,230	19.5
			719	2001	14,433	20.1
5	As case 0 but omit Ouse and Ribble	1,270	138	1981	2,545	18.4
			421	1991	8,841	21.0
			719	2001	15,730	21.9
6	As case 0 but omit Ouse, Ribble and Lune	1,065	138	1981	2,569	18.6
			421	1991	8,921	21.2
			719	2001	15,874	22.1
7	As case 0 but omit Ouse, Ribble, Lune and Kent	898	138	1981	2,641	19.2
			421	1991	9,161	21.7
			719	2001	16,358	22.7

TABLE X/2

EXAMPLE OF COMPUTER SELECTIONS OF SOURCE RIVERS

Case 0

River	Available Yield (m.g.d.)	DESTINATION AND SOURCES SELECTED											
		Newcastle/ Sunderland	Teesside	Hull/Humberside	West Riding (North)	West Riding (South)	Flint/Denbigh	Chester	Liverpool	Manchester	Preston	Cumberland (N.W.)	Remainder
Coquet (Guyzance)													
1981	53												53
1991	–												53
2001	–												53
Tyne (Bywell)													
1981	270	8	–										262
1991	–	40	–										230
2001	–	71	1										198
Wear (Sund' Bridge)													
1981	73		13										60
1991	–		44										29
2001	–		73										0
Tees (Low Worsall)													
1981	65												65
1991	–												65
2001	–												65
Ouse (Selby)													
1981	238			18	–	23							197
1991	–			69	13	54							102
2001	–			116	38	84							0
Derwent (Stamford Bridge)													
1981	45			–									45
1991	–			–									45
2001	–			3									42
Clwyd (Bodfari)													
1981	14						7						7
1991	–						10						4
2001	–						13						1
Dee (Chester)													
1981	110							13					97
1991	–							36					74
2001	–							58	52				0

TABLE X/2 (Contd.)

CASE 0

River	Available Yield (m.g.d.)	DESTINATION AND SOURCES SELECTED											
		Newcastle/ Sunderland	Teesside	Hull/Humberside	West Riding (North)	West Riding (South)	Flint/Denbigh	Chester	Liverpool	Manchester	Preston	Cumberland (N.W.)	Remainder
Ribble (Hodderfoot)													
1981	150								1	–	24		125
1991	–								33	36	44		37
2001	–								13	80	57		0
Lune (Halton)													
1981	205												205
1991	–												205
2001	–												205
Wyre (St. Michaels)													
1981	14										–		14
1991	–										–		14
2001	–										7		7
Kent (Arnside)													
1981	167								–				167
1991	–								–				167
2001	–								–				167
Leven (Greenodd)													
1981	170												170
1991	–												170
2001	–												170
Duddon (Duddon Viaduct)													
1981	56												56
1991	–												–
2001	–												–
Calder/Bleng/Irt													
1981	38												38
1991	–												38
2001	–												38
Derwent (Workington)													
1981	216											31	185
1991	–											42	174
2001	–											53	163
Eden (Carlisle)													
1981	98												98
1991	–												98
2001	–												98

SUMMARY TABLE X/3

COMPUTER SELECTIONS OF INDIVIDUAL RESOURCES

Comparable Table J Programme No.	Resource Selection No.	Program Description	Assumed Total Demands	Total Supplies m.g.d.	Date Supplied	Cost 000d/day	Cost d/1000 gals
— — 1	1B 1A 1	Free Selection of all Inland sources used as ***direct supply***	Net Public Water Supply and Industrial deficiency less probable development of isolated sources.	238 579 928	1981 1991 2001	3.925 10,681 19,652	16.4 18.4 21.2
—	1C	As above	As above but excluding Hull/Humberside deficiency.	810	2001	16.023	19.9
— — 2	3B 3A 3	Free Selection from all available sources used for ***river regulation***		238 546 854	1981 1991 2001	3.791 9,275 14,876	15.9 16.9 17.8
— — 2	4B 4A 4	As above	Net Public Water Supply deficiency less isolated sources.	183 463 745	1981 1991 2001	2,812 7,741 12,861	15.3 16.6 17.3
— — 2	5B 5A 5	As above	Net Public Water Supply and Industrial deficiency less probable development of isolated sources.	238 583 928	1981 1991 2001	3.726 9.826 16,277	15.6 16.8 17.6
—	5X	As above	As above but excluding Hull/Humberside deficiency.	810	2001	14,104	17.5
— — 3	9B 9A 9	Selection of Inland Sources outside National Parks used for regulation	Net Public Water Supply and Industrial deficiency less isolated sources.	238 583 928	1981 1991 2001	3,828 10,143 17,360	16.1 17.5 18.6

TABLE X/3 (Contd.)

Comparable Table J Programme No.	Resource Selection No.	Program Description	Assumed Total Demands	Total Supplies m.g.d.	Date Supplied	Cost 000d/day	Cost d/1000 gals
3	9X	As above	As above but excluding Hull/Humberside deficiency.	810	2001	14,878	18.4
5	6	Nine large sources, two inside National Parks used for regulation	Net Public Water Supply and *revised* industrial demands less isolated sources.	844	2001	17,676	20.9
5	7	Eight large sources, four inside National Parks used for regulation	As above.	844	2001	17,704	21.1
–	8	Morecambe (100) Dee (245) and Solway (47) plus Free Selection	Net Public Water Supply and industrial deficiencies less isolated sources.	928	2001	17,415	18.8
–	8 (1)	Morecambe (450) Dee (216) and Solway (238) plus Free Selection	As above.	928	2001	20,995	22.6
– 8 8	12A 12 12 (1)	Morecambe (340) and Dee (210) plus selection outside National Parks	As above As above but with *revised* industrial deficiencies.	583 928 845	1991 2001 2001	11,985 19,390 17,174	20.6 20.9 20.3
– 9 9	10A 10 10 (1)	Morecambe (480) plus selection of inland sources outside National Parks	Net Public Water Supply and industrial deficiencies less isolated sources. As above but with *revised* industrial deficiencies.	583 928 845	1991 2001 2001	11,885 17,583 19,464	20.4 20.7 21.0
10 10	11 11 (1)	Dee Estuary (250) plus Selection of inland sources outside National Parks	As 10 and 10 (1) above.	928 845	2001 2001	17,793 15,471	19.2 18.3

TABLE X/4

EXAMPLE OF COMPUTER SELECTIONS OF INDIVIDUAL SOURCES

Resource Selection No. 9

Inland Sources outside National Parks and Areas of Outstanding Natural Beauty

COMPUTER SELECTIONS													
DEMAND CENTRE shewing demands (m.g.d.) in				SOURCE	Yield	Usage of Source m.g.d./Cost '000s pence/day							
						1981		1991		2001		2001 less Hull/ Humberside	
	1981	1991	2001			Usage	Cost	Usage	Cost	Usage	Cost	Usage	Cost
NEWCASTLE	14	35	56	Irthing	72	14	182	35	455	56	728	56	728
SUNDERLAND	15	27	40	Witton-le-Wear	91	4		27	405			13	
				Otterstone	210	–				40	600	10	
				Irthing	73	–						17	600
				Derwent I	11	11	214						
TEESSIDE	21	60	99	Derwent I	11			11		11		11	
				Witton-le-Wear	91			49	949	88	1,573	78	
				Egglestone Burn	10	10						10	
				Upper Maize Beck	32	11	296						1,533
W.R. NORTH	17	54	92	Middleton	80			9		34		53	
				New Gouthwaite	24			10		6		12	
				Ex. Washburn	6	6		6		6		6	
				Grimwith	21	11	299	21		21		21	1,895
				Hellifield	89			8	1,047				
				Irthing	73					17			
				Ex.Gouthwaite	8					8	1,918		
W.R. SOUTH	21	51	82	Egglestone Burn	10			10		10			
				Ex. Gouthwaite	8	8		8		–		8	
				New Gouthwaite	24	6		3		18		12	
				Birkby Nab	30			30	1,108	20		30	
				Middleton	80					–			
				Otterstone	210					18			
				Upper Greta	6					6			
				Upper Maize	32							32	1,874
				Grimwith	21	7	445						
HULL/HUMBERSIDE	18	68	118	Middleton or Farndale	–			57		46			
				New Gouthwaite	24	18	306	11	1,270	–			
				Otterstone	210					37			
				Witton-le-Wear	91					3			
				Upper Maize Beck	32					32	2,359		0
FLINT/DENBIGH	15	29	42	Brenig	10	10		26		10		10	
				Tube Wells	3			3	554	3		3	
				Upper Clwyd	10					10		10	
				Brenig	70	5	285			19	910	19	910
CHESTER	31	58	85	Brenig	70	29		22		25		25	
				Twrch	20			20		20		20	
				Hirnant	40			16	974	40	1,475	40	1,475
				Improvements on Dee	13	2	459						

TABLE X/4 (Contd.)

COMPUTER SELECTIONS

DEMAND CENTRE shewing demands (m.g.d.) in			SOURCE	Yield	Usage of Source m.g.d./Cost '000s pence/day							
					1981		1991		2001		2001 less Hull/ Humberside	
1981	1991	2001			Usage	Cost	Usage	Cost	Usage	Cost	Usage	Cost
LIVERPOOL			Improvements on Dee	13	11		13		13		13	
16	36	57	Brenig	70			23	537	24		24	
			Alwen Ex.	4					4		4	
			Hellifield	89					7		7	
			Stankhill Beck	7					7		7	
			Rivington	9	5	218			2	919	2	919
MANCHESTER			Brenig	80			7					
4	44	83	Hellifield	89			27		15		15	
			Stankhill Beck	7			1		–		–	
			Rivington	9	4	68	9	847	7		7	
			Birk Beck	10					9		9	
			Mint (Mealbank)	20					15		15	
			Lupton Beck	19					7		7	
			Peasey Beck	30					30	1,981	30	1,981
PRESTON			Stock Beck	4	4		4		4		4	
14	44	73	Hellifield	89	8		38		67		67	
			Conjunctive Use	2	2	232	2	742	2	1,235	2	1,235
FYLDE			Hellifield	89	11		16					
26	37	48	Stankhill Beck	7			6					
			Boreholes	15	15	382	15	575	15		15	
			Flake Bridge	28					28		28	
			Mint (Mealbank)	20					5	827	5	827
CUMBERLAND			Marron	60	26	442	40	680	53	901	53	901
26	40	53										
238	583	928	Total Cost '000s pence/day =			3,828		10.143		17,360		14,878
mgd	mgd	mgd	Avge. Cost pence/1000 gals. =			16.1		17.5		18.6		18.4

TABLE X/5
SUMMARY SCHEDULE OF ESTIMATED COSTS OF CONSERVATION PROGRAMMES

Programme Number	Total R.I.W.P. Deficiencies Satisfied Plus Exports	Description	Expenditure (to nearest million pounds) £p million: Conservation Works: Land	Conservation Works: Engineering	Intakes, Pumping Plant, Bridges, Pipelines, Power and Maintenance, Transmission	Treatment – New Works and Operation	Treatment – Softening Works and Operation	Terminal Storage	Administration	Total Outlay	Mean Unit Cost Average Unit Cost to 2001 Pence/1000 gals	1970 Value (£ million) Net present value at 1970 of Construction, Maintenance and Operation of Programme in Perpetuity	1970 Unit Value Mean Unit Cost in perpetuity Pence/1000 gals.
		DIRECT SUPPLY SYSTEM											
1	700 m g d + 100 m g d Export	Free selection of inland reservoirs	2	21	210	65	–	29	26	422	29	139	31
		RIVER REGULATION SYSTEM											
2		Free selection of inland reservoirs	1	56	131	78	8	29	36	342	19	101	23
3		Selected inland reservoirs outside National Parks	1	22	150	71	2	29	36	372	21	130	28
4		Direct supply to Manchester from Killington	1	71	132	77	2	21	21	311	21	137	26
5		Eight large inland reservoirs post 1981 mainly outside National Parks	1	25	162	78	2	22	21	331	21	132	25
6		Morecambe, Dee and Solway estuaries post 1981	*	55	123	78	1	29	22	402	22	112	20
7		Morecambe and Solway estuaries post 1981	*	51	222	78	8	28	52	421	22	186	28
8		Morecambe and Dee estuaries post 1981	*	68	172	71	1	29	36	387	21	111	27
9		Morecambe estuary post 1981	1	76	200	78	7	21	36	412	23	149	27
10		Dee estuary post 1981	1	73	151	78	1	21	23	372	21	132	25
11	700 m g d No Export	Selected inland reservoirs inside National Parks	1	58	132	65	7	22	31	317	21	111	22
12		Seven large inland reservoirs post 1981 outside National Parks	1	66	137	78	1	26	32	330	24	116	22
13		Morecambe estuary	1	50	151	79	7	22	21	322	21	122	27
14	700 m g d + 100 m g d Export + 272 m g d Yield on River Severn	Selection of inland reservoirs (R. Dee resources regulating the R. Severn and yielding 272 m g d)	1	81	121	101	8	41	45	377	21	152	22
15		Selection of inland reservoirs outside National Parks (R. Dee resources regulating the R. Severn and yielding 272 m g d)	1	15	216	109	1	81	48	507	22	168	22
16		Eight large inland reservoirs post 1981 outside National Parks (R. Dee resources regulating the R. Severn and yielding 272 m g d)	1	93	227	102	1	41	46	519	23	179	22
17		Morecambe estuary (R. Dee resources regulating the R. Severn and yielding 272 m g d)	1	65	198	102	2	41	12	328	22	172	21
18	700 m g d + 100 m g d Export + 500 m g d Yield on River Severn	Estuarial and inland reservoirs (R. Dee and other resources producing 500 m g d yield on the R. Severn)	1	112	215	230	1	50	68	765	28	241	31

Notes § Tentative estuarial sites and isolated barrages
* Expenditure less than £1 million

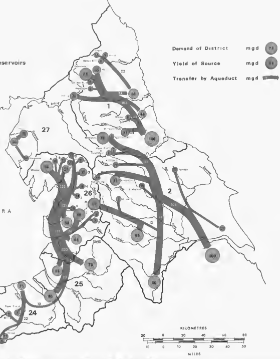
DIRECT SUPPLY SYSTEM
2001

Programme No **1**

Free Selection of Inland Reservoirs

LANCASHIRE SOURCES

A [illegible]
B [illegible]
C [illegible]
D [illegible]
E [illegible]
F [illegible]
G [illegible]
H [illegible]
J [illegible]
K [illegible]
L [illegible]
M [illegible]
N [illegible]
P [illegible]



River Authorities

1 NORTHUMBRIAN R A
2 YORKSHIRE OUSE & HULL R A
24 DEE & CLWYD R A
25 MERSEY & WEAVER R A
26 LANCASHIRE R A
27 CUMBERLAND R A

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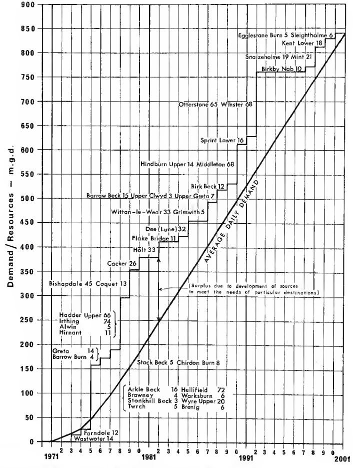
Fig No 1b

DEMAND / RESOURCES DEVELOPMENT

Direct Supply System – Free Selection of Inland Reservoirs



ACTUAL AND DISCOUNTED ANNUAL EXPENDITURES

(CAPITAL, MAINTENANCE AND OPERATION)

Direct Supply System - Free Selection of Inland Reservoirs

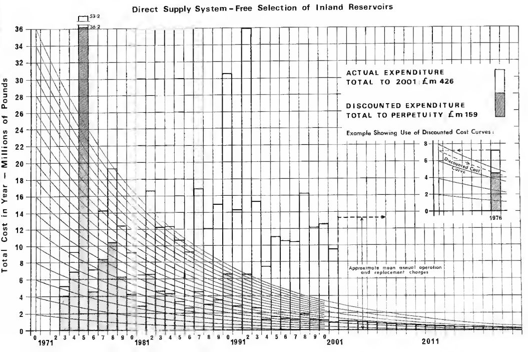


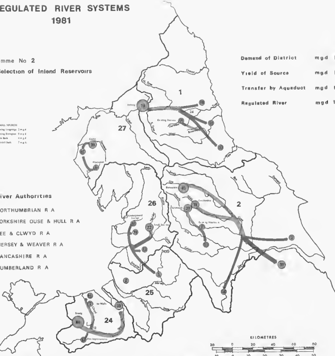
Fig No 1c

Fig No 2a(i)

REGULATED RIVER SYSTEMS
1981

Programme No 2

Free Selection of Inland Reservoirs



River Authorities

1 NORTHUMBRIAN R A

2 YORKSHIRE OUSE & HULL R A

24 DEE & CLWYD R A

25 MERSEY & WEAVER R A

26 LANCASHIRE R A

27 CUMBERLAND R A

REGULATED RIVER SYSTEMS
1990

Programme No 2

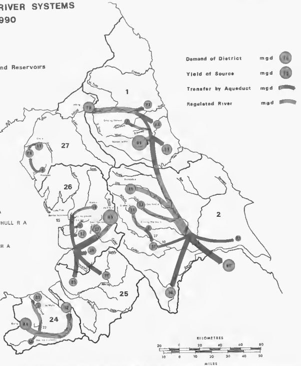
Free Selection of Inland Reservoirs

RIBBLE SMALL SOURCES

Existing Loughrigg	2 m g d
Existing Rivington	4 m g d
Stock Beck	3 m g d
Swanside Beck	7 m g d

River Authorities

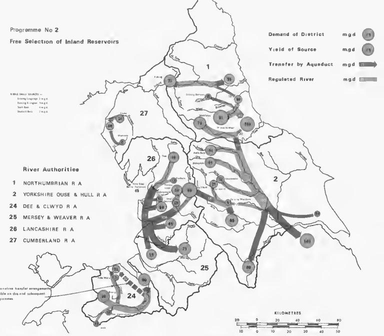
- 1 NORTHUMBRIAN R A
- 2 YORKSHIRE OUSE & HULL R A
- 24 DEE & CLWYD R A
- 25 MERSEY & WEAVER R A
- 26 LANCASHIRE R A
- 27 CUMBERLAND R A



REGULATED RIVER SYSTEMS
2001

Programme No 2

Free Selection of Inland Reservoirs



Demand of District	mgd	79
Yield of Source	mgd	79
Transfer by Aqueduct	mgd	25
Regulated River	mgd	25

River Authorities

1 NORTHUMBRIAN R A

2 YORKSHIRE OUSE & HULL R A

24 DEE & CLWYD R A

25 MERSEY & WEAVER R A

26 LANCASHIRE R A

27 CUMBERLAND R A

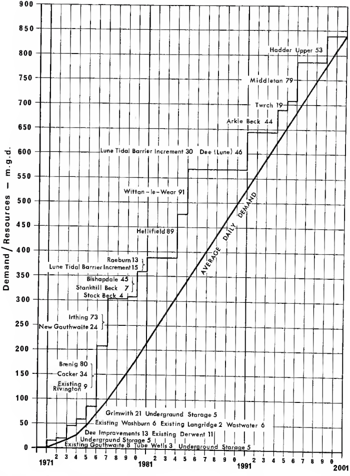
R BBLE SMALL SOURCES —

Existing Longridge	3 m g d.
Barning R ington	9 m g d.
Stock Beck	4 m g d.
Swoboll Beck	7 m g d.

rnative transfer arrangements
ible on this and subsequent
grammes

DEMAND / RESOURCES DEVELOPMENT

Free Selection of Inland Reservoirs



ACTUAL AND DISCOUNTED ANNUAL EXPENDITURES

(CAPITAL, MAINTENANCE AND OPERATION)

Free Selection of Inland Reservoirs

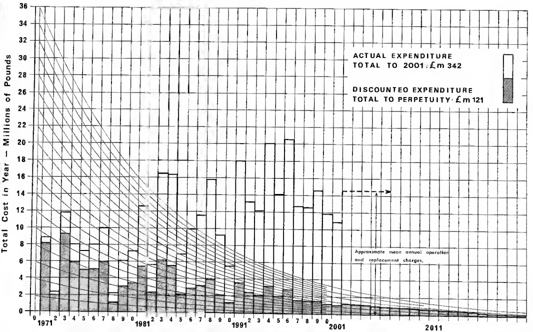
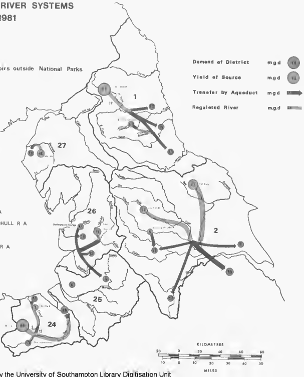


Fig No 2c

REGULATED RIVER SYSTEMS
1981

Programme No 3

Selected Inland Reservoirs outside National Parks



River Authorities

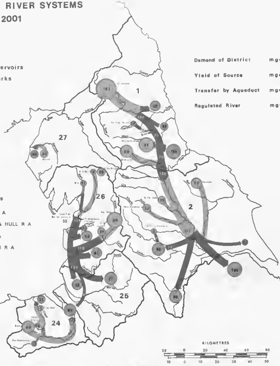
1 NORTHUMBRIAN R A
2 YORKSHIRE OUSE & HULL R A
24 DEE & CLWYD R A
25 MERSEY & WEAVER R A
26 LANCASHIRE R A
27 CUMBERLAND R A

Fig No 3a(ii)

REGULATED RIVER SYSTEMS
2001

Programme No 3

Selected Inland Reservoirs outside National Parks



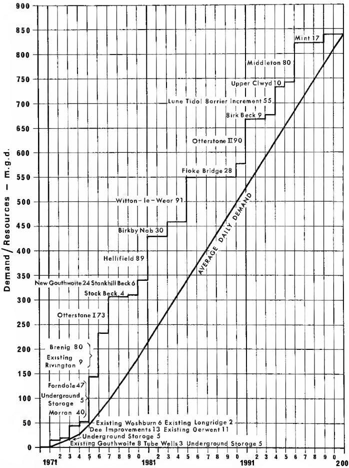
River Authorities

1 NORTHUMBRIAN R A
2 YORKSHIRE OUSE & HULL R A
24 DEE & CLWYD R A
25 MERSEY & WEAVER R A
26 LANCASHIRE R A
27 CUMBERLAND R A

Fig. No. 3b.

DEMAND / RESOURCES DEVELOPMENT

Selected Inland Reservoirs outside National Parks



ACTUAL AND DISCOUNTED ANNUAL EXPENDITURES

(CAPITAL, MAINTENANCE AND OPERATION)

Selected Inland Reservoirs outside National Parks

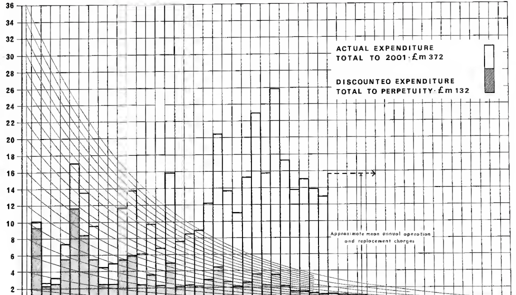


Fig No 3c

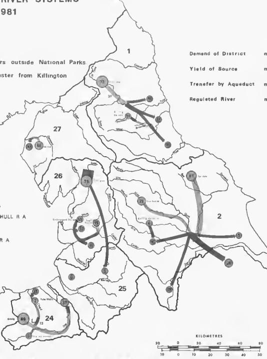
Fig No 4a(i)

REGULATED RIVER SYSTEMS
1981

Programme No 4

Selected Inland Reservoirs outside National Parks

Direct supply to Manchester from Killington



River Authorities

1 NORTHUMBRIAN R A

2 YORKSHIRE OUSE & HULL R A

24 DEE & CLWYD R A

25 MERSEY & WEAVER R A

26 LANCASHIRE R A

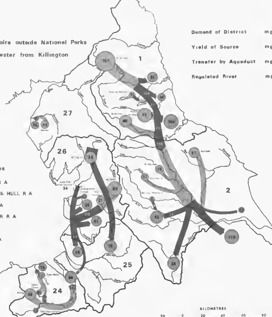
27 CUMBERLAND R A

REGULATED RIVER SYSTEMS
2001

Programme No 4

Selected Inland Reservoire outside National Parks

Direct Supply to Manchester from Killington



River Authorities

1 NORTHUMBRIAN R A

2 YORKSHIRE OUSE & HULL R A

24 DEE & CLWYD R A

25 MERSEY & WEAVER R A

26 LANCASHIRE R A

27 CUMBERLAND R A

Fig No 4b

DEMAND / RESOURCES DEVELOPMENT

Selected Inland Reservoirs outside National Parks
Direct Supply to Manchester from Killington

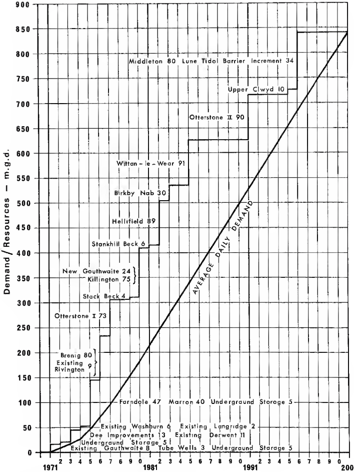


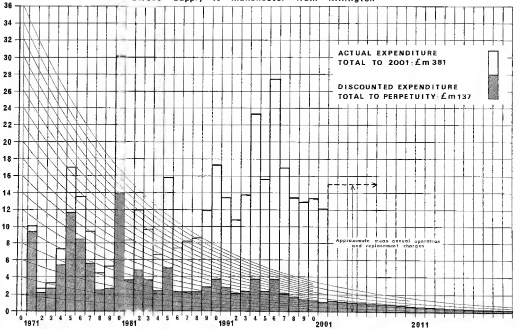
Fig No 4c

ACTUAL AND DISCOUNTED ANNUAL EXPENDITURES

(CAPITAL, MAINTENANCE AND OPERATION)

Selected Inland Reservoirs outside National Parks

Direct Supply to Manchester from Killington

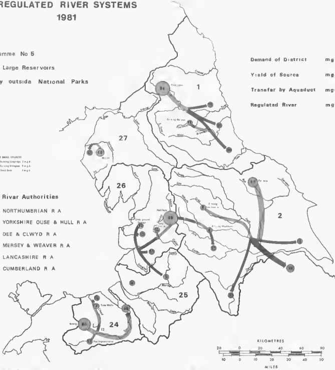


REGULATED RIVER SYSTEMS
1981

Programme No 5

Eight Large Reservoirs

mainly outside National Parks



River Authorities

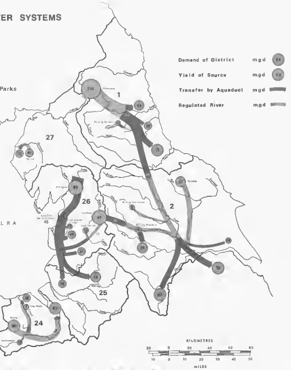
- 1 NORTHUMBRIAN R A
- 2 YORKSHIRE OUSE & HULL R A
- 24 DEE & CLWYD R A
- 25 MERSEY & WEAVER R A
- 26 LANCASHIRE R A
- 27 CUMBERLAND R A

Fig No 5a (ii)

REGULATED RIVER SYSTEMS 1995

Programme No 5

Eight Large Reservoirs mainly outside National Parks



River Authorities

1 NORTHUMBRIAN R A

2 YORKSHIRE OUSE & HULL R A

24 DEE & CLWYD R A

25 MERSEY & WEAVER R A

26 LANCASHIRE R A

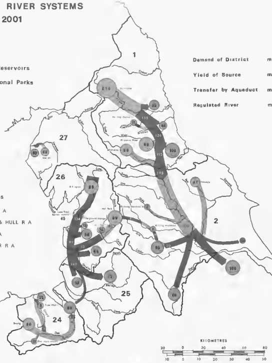
27 CUMBERLAND R A

REGULATED RIVER SYSTEMS
2001

Programme No 5

Eight Large Inland Reservoirs

mainly outside National Parks



RIBBLE SMALL SOURCES
Existing Longridge 2 m.g.d.
Existing Rivington 9 m.g.d.
Stocks Bank 4 m.g.d.

River Authorities

1 NORTHUMBRIAN R A
2 YORKSHIRE OUSE & HULL R A
24 DEE & CLWYD R A
25 MERSEY & WEAVER R A
26 LANCASHIRE R A
27 CUMBERLAND R A

Fig No 5b

DEMAND / RESOURCES DEVELOPMENT

Eight Large Inland Reservoirs mainly outside National Parks

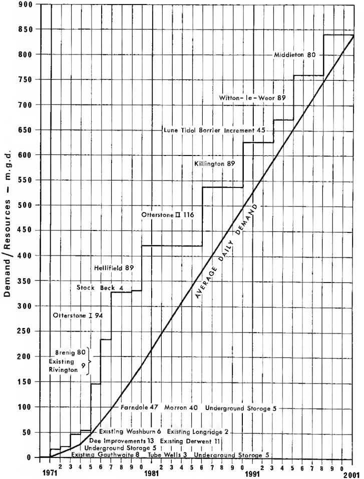


Fig No 5c

ACTUAL AND DISCOUNTED ANNUAL EXPENDITURES

(CAPITAL, MAINTENANCE AND OPERATION)

Eight Large Inland Reservoirs
mainly outside National Parks

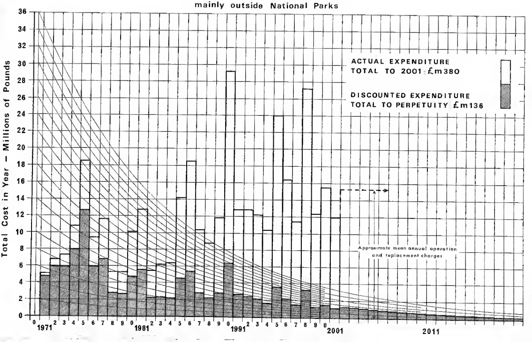


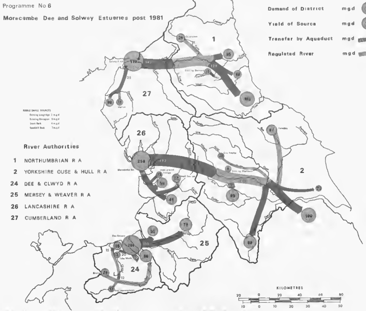
Fig No 6a

REGULATED RIVER SYSTEMS
2001

(1981 Development similar to Programme No 3)

Programme No 6

Morecambe Dee and Solwey Estueries post 1981

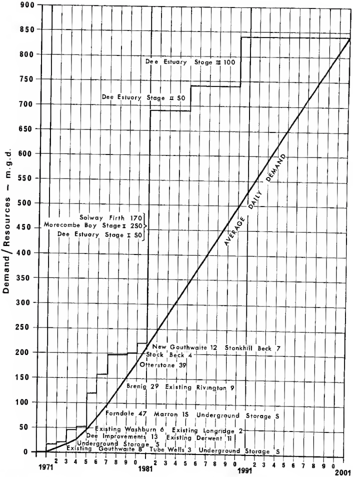


River Authorities

- 1 NORTHUMBRIAN R A
- 2 YORKSHIRE OUSE & HULL R A
- 24 DEE & CLWYD R A
- 25 MERSEY & WEAVER R A
- 26 LANCASHIRE R A
- 27 CUMBERLAND R A

DEMAND / RESOURCES DEVELOPMENT

Morecambe Dee and Solway Estuaries post 1981



ACTUAL AND DISCOUNTED ANNUAL EXPENDITURES

(CAPITAL, MAINTENANCE AND OPERATION)

Morecambe Dee and Solway Estuaries post 1981

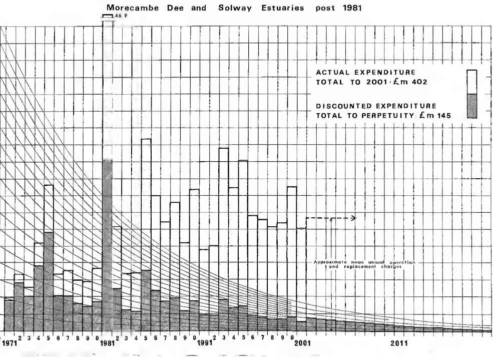


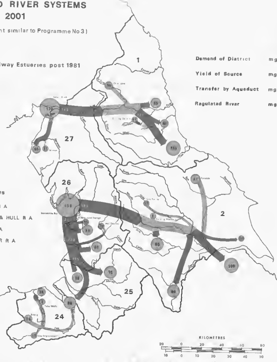
Fig. No. 6c

REGULATED RIVER SYSTEMS
2001

(1981 Development similar to Programme No 3)

Programme No 7

Morecambe and Solway Estuaries post 1981



River Authorities

- 1 NORTHUMBRIAN R A
- 2 YORKSHIRE OUSE & HULL R A
- 24 DEE & CLWYD R A
- 25 MERSEY & WEAVER R A
- 26 LANCASHIRE R A
- 27 CUMBERLAND R A

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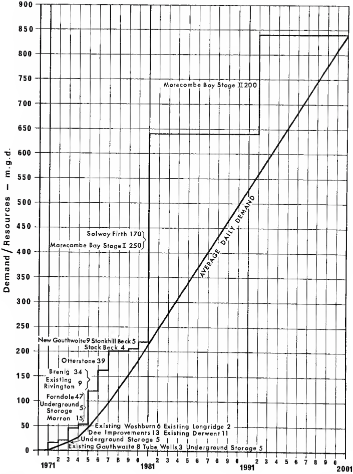
Fig. No 7 b

DEMAND / RESOURCES DEVELOPMENT

Morecambe and Solway Estuaries post 1981



ACTUAL AND DISCOUNTED ANNUAL EXPENDITURES

(CAPITAL, MAINTENANCE AND OPERATION)

Morecambe and Solway Estuaries post 1981

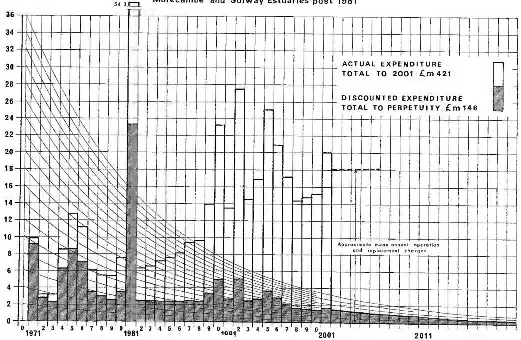


Fig No 7c

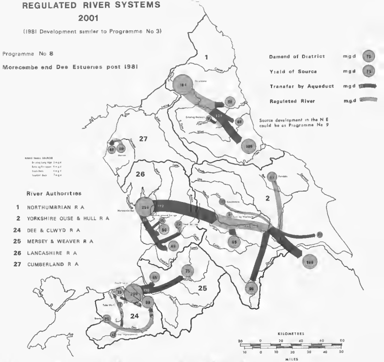
Fig No 8a

REGULATED RIVER SYSTEMS
2001

(1981 Development similar to Programme No 3)

Programme No 8

Morecambe and Dee Estuaries post 1981



River Authorities

1 NORTHUMBRIAN R A

2 YORKSHIRE OUSE & HULL R A

24 DEE & CLWYD R A

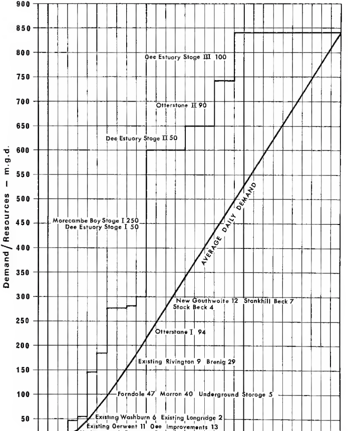
25 MERSEY & WEAVER R A

26 LANCASHIRE R A

27 CUMBERLAND R A

DEMAND / RESOURCES DEVELOPMENT

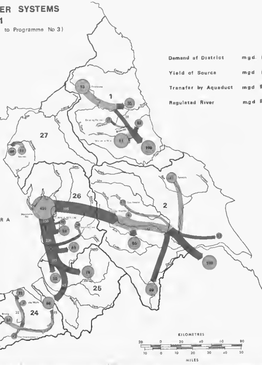
Morecambe and Dee Estuaries post 1981



REGULATED RIVER SYSTEMS 2001

(1981 Development similar to Programme No 3)

Programme No 9
Morecambe Estuary post 1981



River Authorities

1 NORTHUMBRIAN R A
2 YORKSHIRE OUSE & HULL R A
24 DEE & CLWYD R A
25 MERSEY & WEAVER R A
26 LANCASHIRE R A
27 CUMBERLAND R A

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Fig No 9b

DEMAND / RESOURCES DEVELOPMENT

Morecambe Estuary post 1981

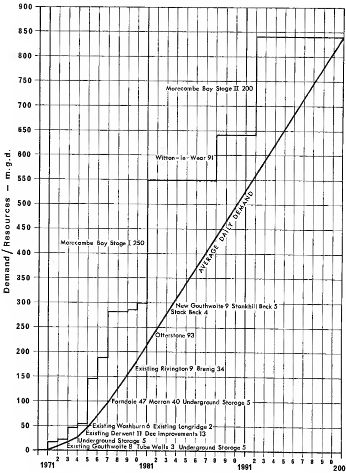


Fig No 9c

ACTUAL AND DISCOUNTED ANNUAL EXPENDITURES

(CAPITAL, MAINTENANCE AND OPERATION)

Morecambe Estuary post 1981

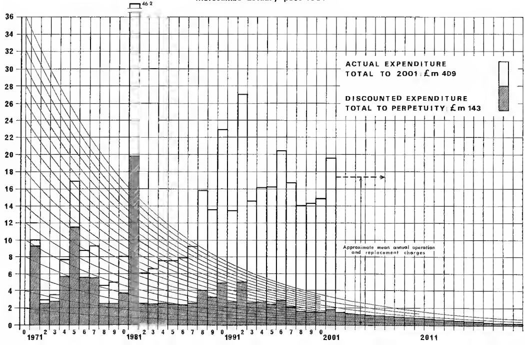


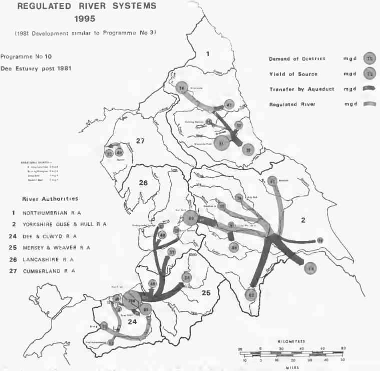
Fig No 10a(i)

REGULATED RIVER SYSTEMS 1995

(1981 Development similar to Programme No 3)

Programme No 10

Dee Estuary post 1981



River Authorities

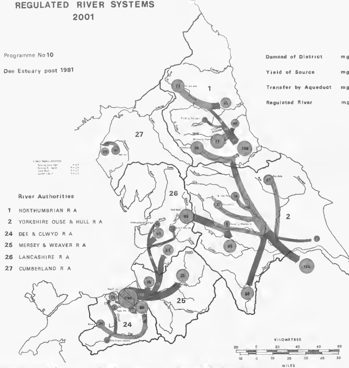
- 1 NORTHUMBRIAN R A
- 2 YORKSHIRE OUSE & HULL R A
- 24 DEE & CLWYD R A
- 25 MERSEY & WEAVER R A
- 26 LANCASHIRE R A
- 27 CUMBERLAND R A

Fig No 10a(ii)

REGULATED RIVER SYSTEMS
2001

Programme No 10

Dee Estuary post 1981



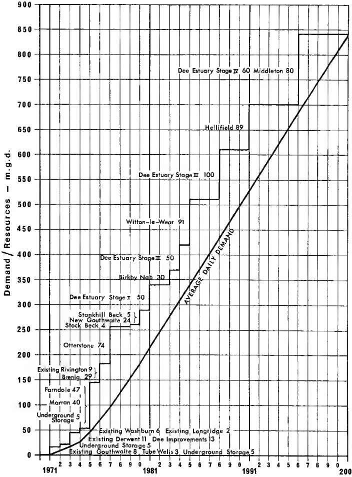
River Authorities

1 NORTHUMBRIAN R A
2 YORKSHIRE OUSE & HULL R A
24 DEE & CLWYD R A
25 MERSEY & WEAVER R A
26 LANCASHIRE R A
27 CUMBERLAND R A

Fig. No.10 b

DEMAND / RESOURCES DEVELOPMENT

Dee Estuary post 1981



WATER RESOURCES BOARD PUBLICATIONS

No. 1 Water Supplies in South East England 1966 £3 3s. (out of print)

No. 2 Morecambe Bay Barrage: Desk Study: Report of Consultants 1966 £1 2s. 6d. (23s. 10d.)

No. 3 Solway Barrage: Desk Study: Report of Consultants 1966 16s. (17s. 2d.)

No. 4 Morecambe and Solway Barrages: Report on Desk Studies 10s. 6d. (11s. 2d.)

No. 5 Interim Report on Water Resources in the North 12s. (12s. 8d.)

No. 6 Report on Desalination for England and Wales 4s. (4s. 6d.)

No. 7 Water Resources in the North: Northern Technical Working Party Report £9 10s. 0d.

No. 8 Water Resources in the North—Report by the Water Resources Board £1 16s. 0d.

Prices in brackets include postage

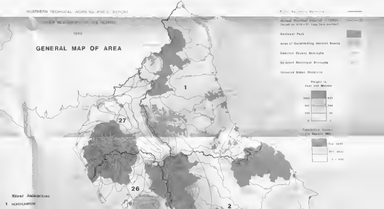
MAP No 1

NORTHERN TECHNICAL WORKING PARTY REPORT

WATER RESOURCES OF THE NORTH

1969

GENERAL MAP OF AREA

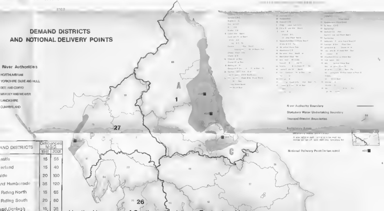


NORTHERN TECHNICAL WORKING PARTY REPORT

WATER RESOURCES IN THE NORTH

1969

DEMAND DISTRICTS AND NOTIONAL DELIVERY POINTS



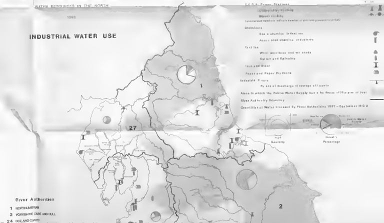
AND DISTRICTS	Deficiencies M.G.D.	
	1981	2001
astle	15	55
erland	15	40
side	20	100
nd Humberside	35	120
Riding North	15	65
Riding South	20	60
nd Denbigh	15	35

ORTHERN TECHNICAL

WATER RESOURCES IN THE NORTH

1969

INDUSTRIAL WATER USE


C.E.G.B. Power Stations
Evaporative cooling
Direct cooling
(enumerated symbols indicate number of stations grouped together)
Chemicals
Basic chemical industries
Associated chemical industries
Textiles
Wool woollens and worsteds
Cotton and Spinning
Iron and Steel
Paper and Paper Products
Industrial Rivers
Points of discharge of sewage effluents
Areas in which the Public Water Supply has a hardness of 75 p.p.m. or over
River Authority Boundary
Quantities of Water Licensed by River Authorities 1967 – Equivalent M.G.D.
Public Water Supply
Industry
Quantity
Percentage
1
27
2
River Authorities
1 NORTHUMBRIAN
2 YORKSHIRE OUSE AND HULL
24 DEE AND CLWYD

MAP No

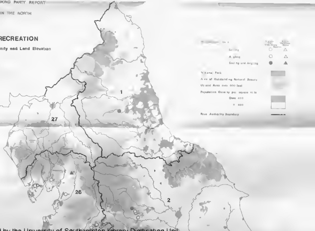
NORTHERN TECHNICAL WORKING PARTY REPORT

WATER RESOURCES IN THE NORTH

1968

AMENITY AND RECREATION

in relation to Population Density and Land Elevation



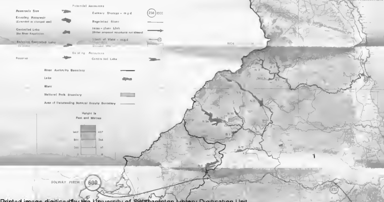
River Authorities

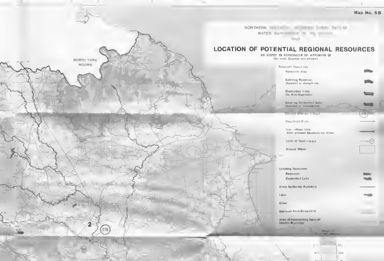
1 NORTHUMBRIAN
2 YORKSHIRE OUSE AND HULL
24 DEE AND CLWYD

NORTHERN TECHNICAL WORKING PARTY REPORT
WATER RESOURCES IN THE NORTH
1969

LOCATION OF POTENTIAL REGIONAL RESOURCES

AS LISTED IN SCHEDULE II OF APPENDIX IX
(Isolated Sources not shown)





Map No. 5B

NORTHERN TEC[illegible]
WATER RE[illegible]
[illegible]

LOCATION OF POTENTIAL REGIONAL RESOURCES

AS LISTED IN SCHEDULES OF APPENDIX IX
([illegible] Sources not shown)

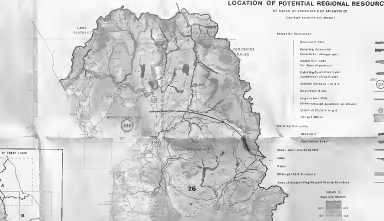
Map No

NORTHERN TECHNICAL WORKING PARTY REPORT
WATER RESOURCES IN THE NORTH
1969

LOCATION OF POTENTIAL REGIONAL RESOURC

AS LISTED IN SCHEDULE II OF APPENDIX IX

(Isolated sources not shown)



MAP No

NORTHERN TECHNICAL [illegible]

WATER RESOURCES IN THE NORTH

1969

CANALS